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GEORGIA INSTITUTE OF TECHNOLOGY
ENGINEERING EXPERIMENT STATION

PROJECT INITIATION

Date: August 15, 1975

Project Title: Central Receiver Solar Thermal Power System

Project No.: A-1759

Project Director: Dr. Steve H. Bomar

Sponsor: Martin Marietta Corporation, Denver, Colorado

Agreement Period: From June 23, 1975 Until September 30, 1975*

Type Agreement: RC5-230340* Subcontract under Government Prime ERDA Contract No. E(04-3)-1110

Amount: $93,580.00

Reports Required: Monthly Progress Reports

Sponsor Contact Person:

Technical Matters
Mr. Guy C. Gualtieri
Martin Marietta Corporation
P.O. Box 179
Mail Stop 2330
Denver, Colorado 80201
303-794-5211, Ext. 3229

Administrative Matters
Mr. R. L. Thompson
Contract Administrator
Martin Marietta Corporation
P.O. Box 179
Mail Stop 2330
Denver, Colorado 80201
303-794-5211 Ext. 7655

*Advance Authority (Sent 7/3/75)

Assigned to: Energy & Materials Technology Division

COPIES TO:

Project Director
Director, EES
Assistant Director
Division Chief
EES Accounting
Patent Coordinator

EES Supply Services
Security–Reports–Property Office
General Office Services
Library, Technical Reports Section
Office of Computing Services
Project File
Other Sue Corbin; Bonnee Wettlaufer

RA-3 (8-75)

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: 10/27/80

Project Title: Central Receiver Solar Thermal Power

Project No: A-1759

Project Director: Dr. Steve H. Bomar

Sponsor: Martin Marietta Corporation

Effective Termination Date: 7/20/79

Clearance of Accounting Charges: 7/20/79

Grant/Contract Closeout Actions Remaining:

_ Final Invoice and Closing Documents

_ Final Fiscal Report

X Final Report of Inventions

X Govt. Property Inventory & Related Certificate

_ Classified Material Certificate

X Other Subcontractor Closeout

Assigned to: TAL (~~School~~/Laboratory)

COPIES TO:

Project Director
Division Chief (EES)
School/Laboratory Director
Dean/Director—EES
Accounting Office
Procurement Office
Security Coordinator (OCA)
Reports Coordinator (OCA)

Library, Technical Reports Section
EES Information Office
Project File (OCA)
Project Code (GTRI)
Other ______

CA-4 (1/79)

H-1731

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

September 9, 1976

Martin Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John Myers
Mail No. S-0403

Subject: Transmittal of Broyles & Broyles Research Experiment Construction Schedule under MMC Contract RC5-230340

Gentlemen:

Attached herewith are two (2) copies of subject.

Sincerely yours,

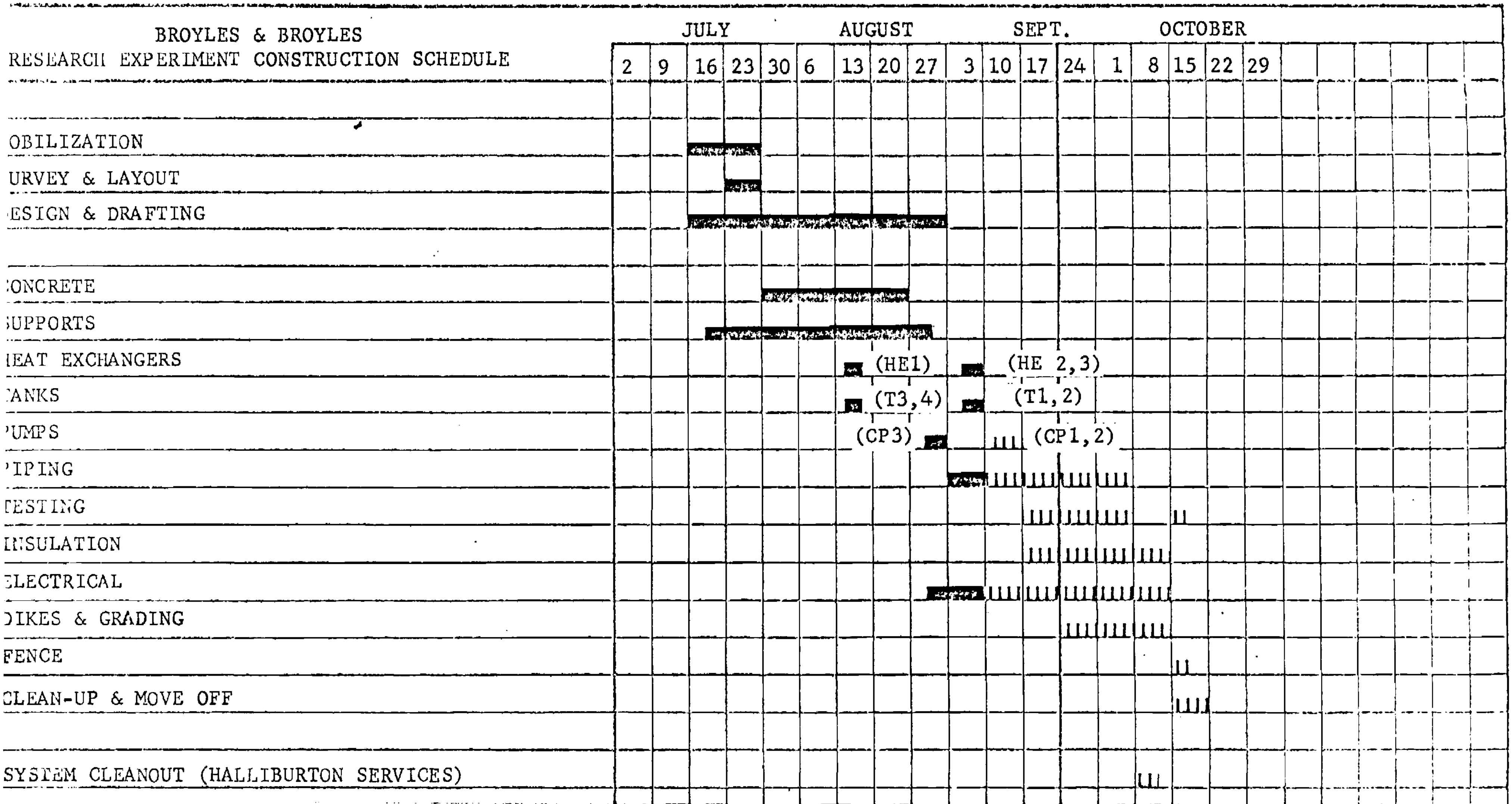
Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

jj

Enclosure: Two (2) copies of Broyles & Broyles Research Experiment Construction Schedule

cc: Ray Ernest, MMC
Bill Phillips, MMC
Al Becker, GIT ✓
File A-1759 Schedules

BROYLES & BROYLES
RESEARCH EXPERIMENT CONSTRUCTION SCHEDULE



NOTE: ALTHOUGH THE GEORGIA TECH MASTER SCHEDULE SHOWS AN OCTOBER 30 COMPLETION DATE FOR INSTALLATION SUBCONTRACT, BROYLES & BROYLES IS WORKING WITH AN OCTOBER 15 DEADLINE. THE TWO-WEEK DIFFERENTIAL PROVIDES GEORGIA TECH A SMALL MARGIN FOR POTENTIAL SCHEDULE SLIPPAGE ON THE PART OF THE CONTRACTOR.

Date 9/3/76

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

October 5, 1976

Martin Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John Myers
Mail No. S-0403

Subject: Transmittal of Broyles & Broyles Research Experiment Construction Schedule under MMC Contract RC5-230340

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Technology Division

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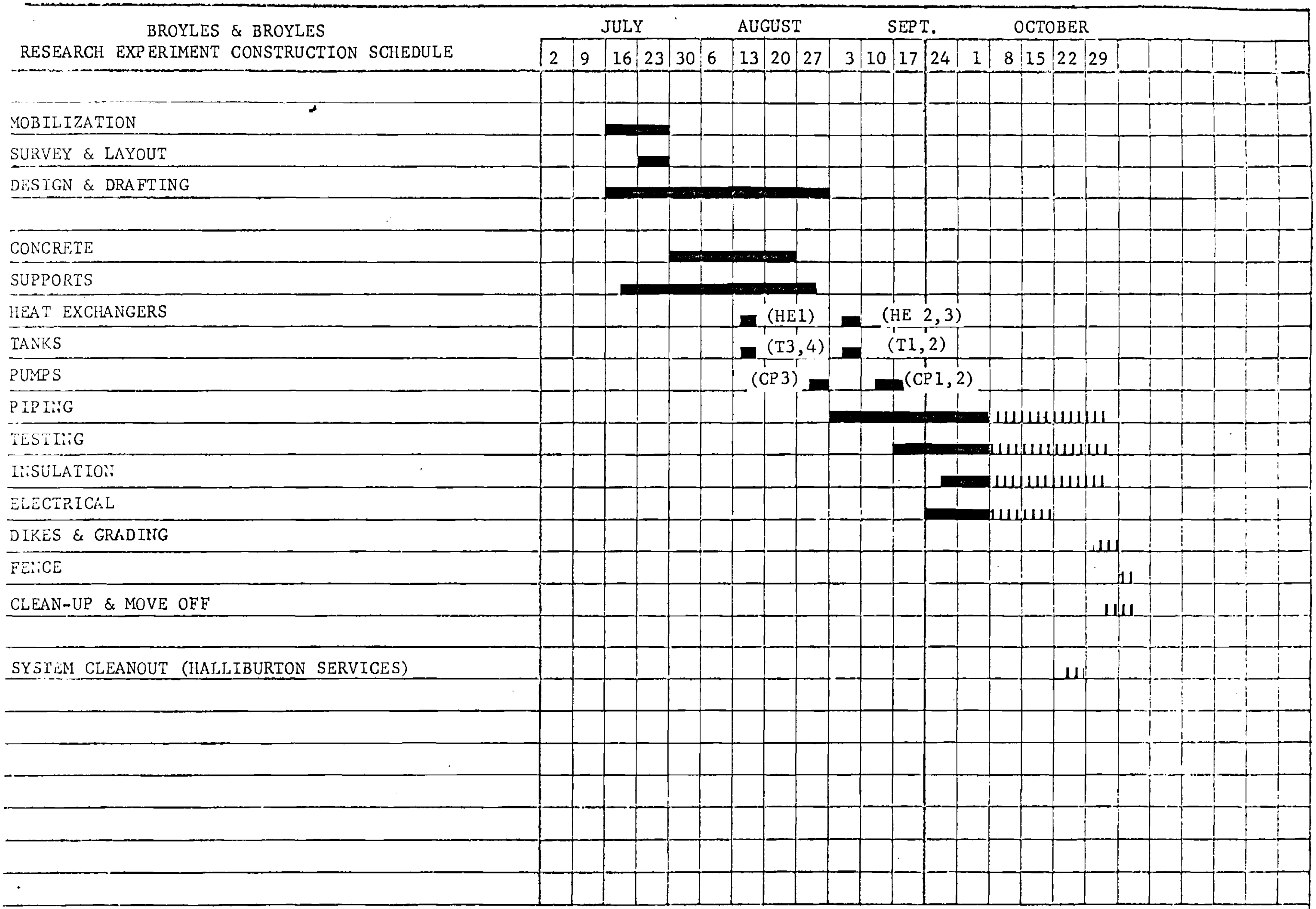
Bill Phillips, MMC
Al Becker, GIT ✓
File A-1759 Schedules

BROYLES & BROYLES

RESEARCH EXPERIMENT CONSTRUCTION SCHEDULE



Engineering Experiment Station
Georgia Institute of Technology

Date 10/1/76

A-1759

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

July 1, 1976

Martin Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

Attention: Mr. John E. Myers
Mail No. S-0403

Subject: Transmittal of Georgia Tech Program Schedule under MMC Contract RC5-230340

Gentlemen:

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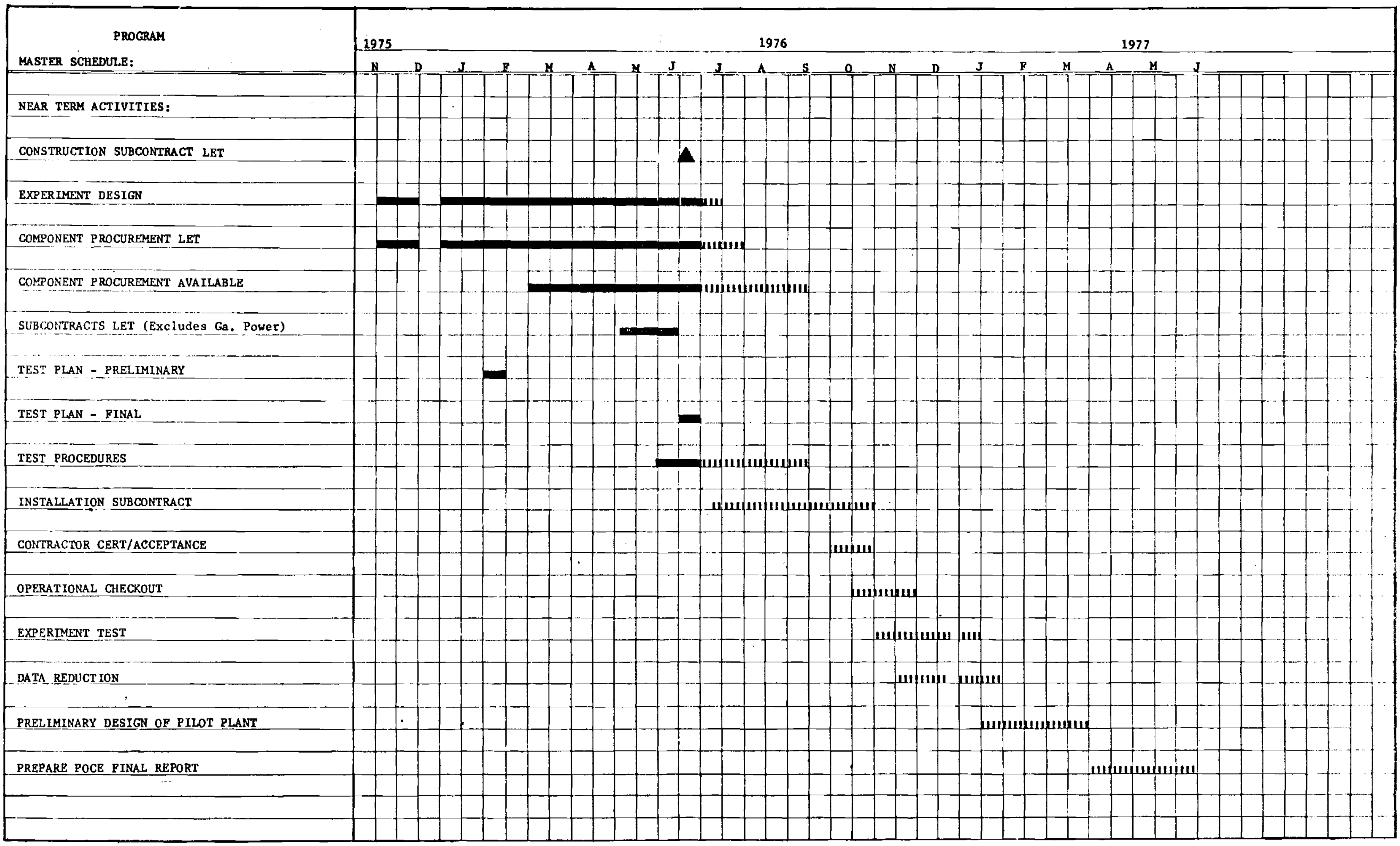
Sincerely yours,

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

jj

Enclosure: Two (2) copies of Georgia Tech Schedule

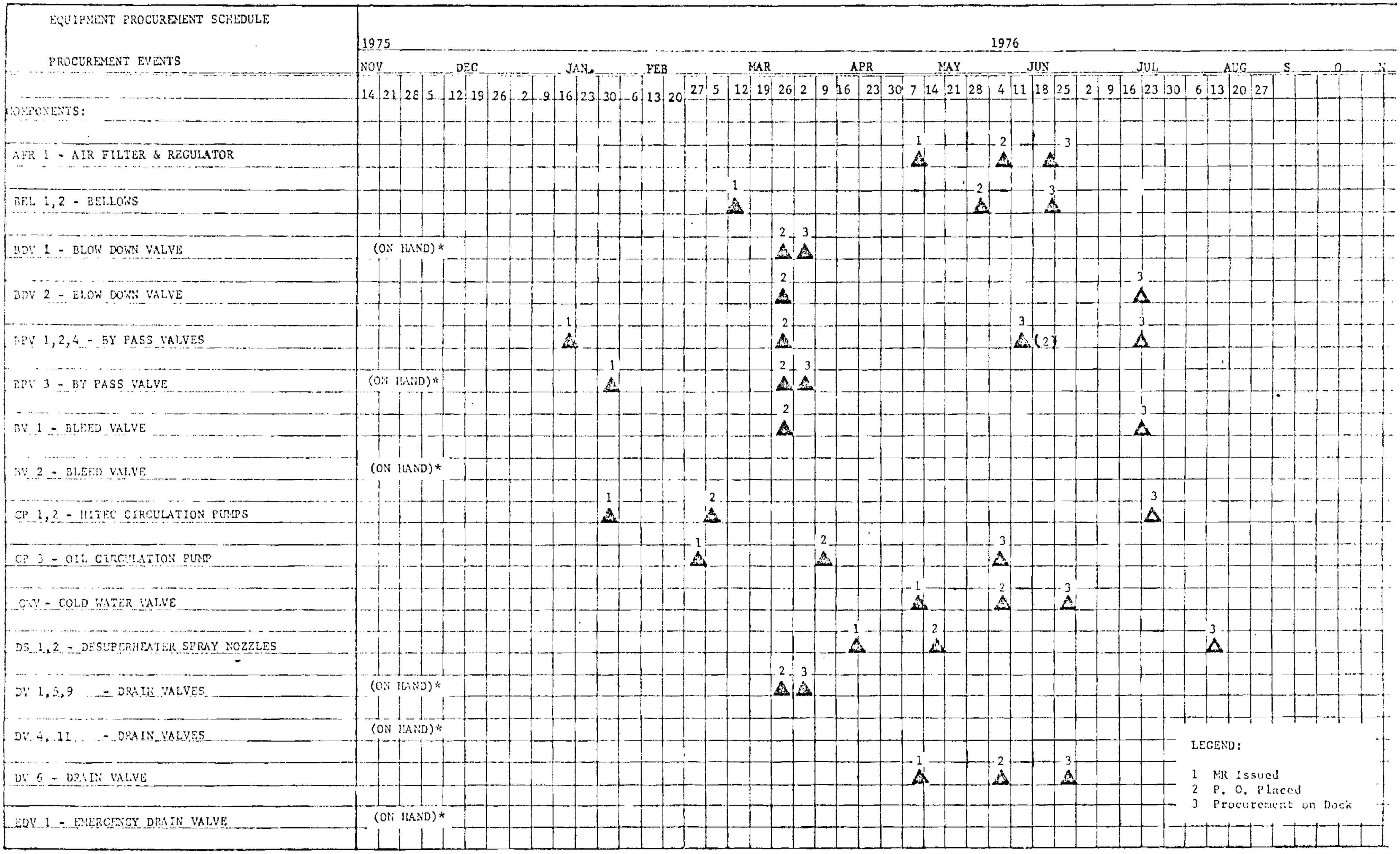
cc: Ray Ernest, MMC
Al Becker, GIT ✓
File A-1759 Schedules



Engineering Experiment Station
Georgia Institute of Technology

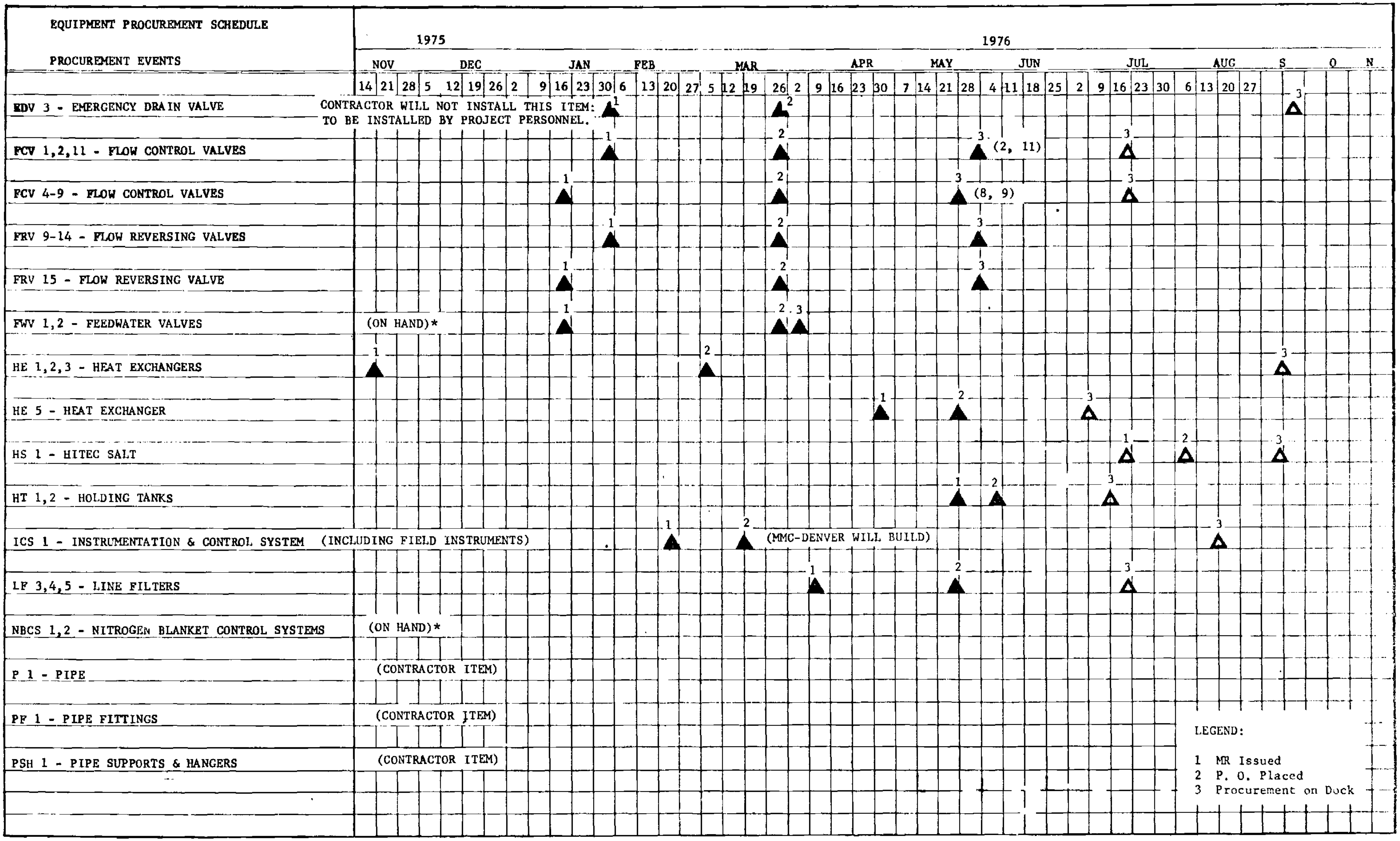
Date 6/30/76 Rev. Ltr. E

Page 1



Engineering Experiment Station
Georgia Institute of Technology

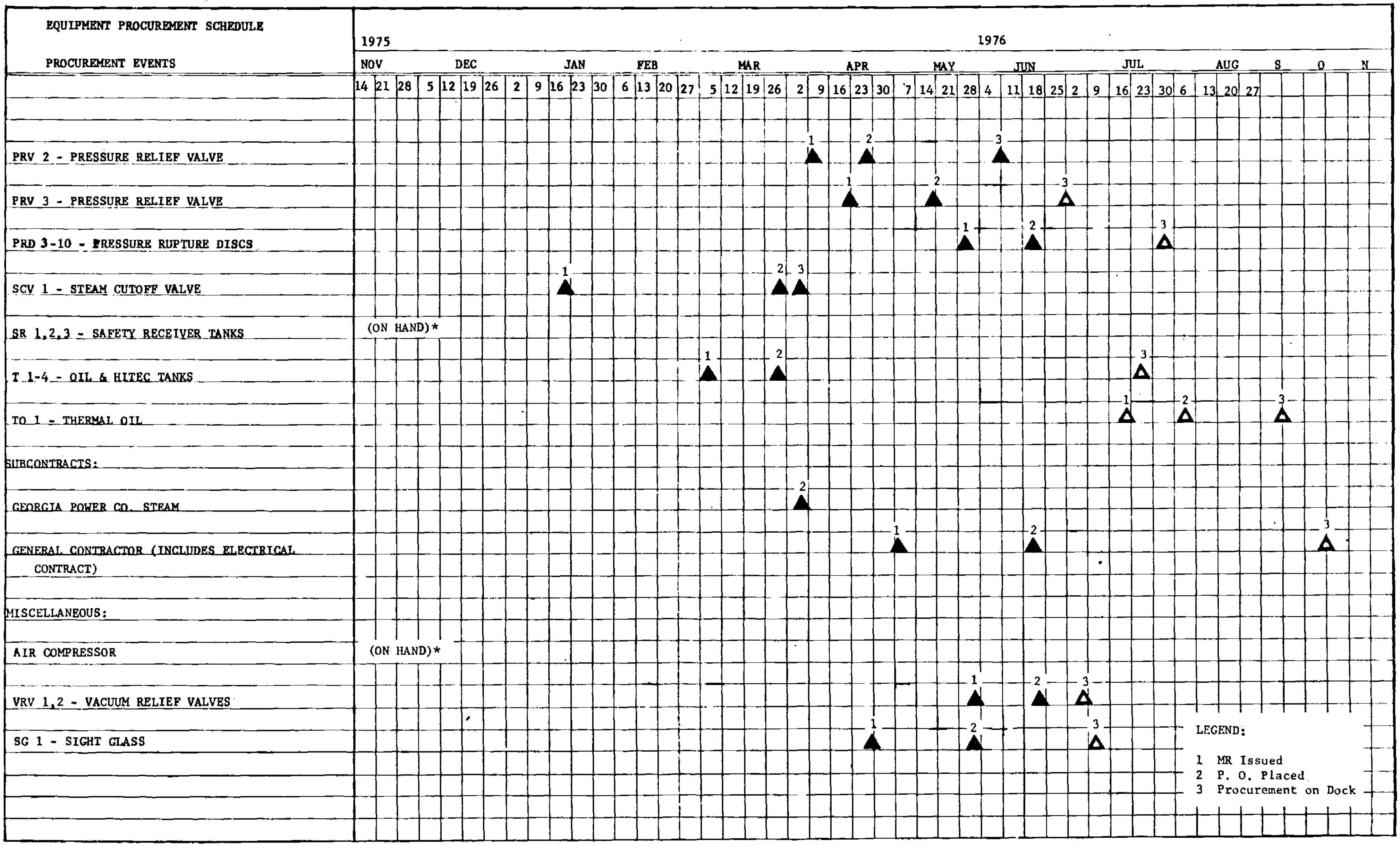
Date 6/30/76 Rev. Ltr. E



Engineering Experiment Station
Georgia Institute of Technology

Date 6/30/76 Rev. Ltr. E

Page 3


EQUIPMENT PROCUREMENT SCHEDULE
PROCUREMENT EVENTS
1975
1976
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
S
O
N
PRV 2 - PRESSURE RELIEF VALVE
PRV 3 - PRESSURE RELIEF VALVE
PRD 3-10 - PRESSURE RUPTURE DISCS
SCV 1 - STEAM CUTOFF VALVE
SR 1,2,3 - SAFETY RECEIVER TANKS
(ON HAND)*
T 1-4 - OIL & HITEC TANKS
TO 1 - THERMAL OIL
SUBCONTRACTS:
GEORGIA POWER CO. STEAM
GENERAL CONTRACTOR (INCLUDES ELECTRICAL CONTRACT)
MISCELLANEOUS:
AIR COMPRESSOR
(ON HAND)*
VRV 1,2 - VACUUM RELIEF VALVES
SG 1 - SIGHT GLASS
LEGEND:
1 MR Issued
2 P. O. Placed
3 Procurement on Dock

EQUIPMENT PROCUREMENT SCHEDULE

PROCUREMENT EVENTS — 1975: NOV, DEC; 1976: JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, S, O, N

Weeks: 14, 21, 28, 5, 12, 19, 26, 2, 9, 16, 23, 30, 6, 13, 20, 27, 5, 12, 19, 26, 2, 9, 16, 23, 30, 7, 14, 21, 28, 4, 11, 18, 25, 2, 9, 16, 23, 30, 6, 13, 20, 27

ADDITIONAL ITEMS:

Item	1 MR Issued	2 P. O. Placed	3 Procurement on Dock
AFR2 - AIR FILTER & REGULATOR	▲ 7 (May)	▲ 4 (Jun)	▲ 18 (Jun)
BDV3 - BLOW DOWN VALVE	(ON HAND)*		
BPV 5, 6 - BY PASS VALVES	(ON HAND)*		
BV3 - BLEED VALVE	(ON HAND)*		
HT3 - HOLDING TANK	(ON HAND)*		
NBCS3 - NITROGEN BLANKET CONTROL SYSTEM	(ON HAND)*		
NCV1 - NITROGEN CHECK VALVE	▲ 28 (May)	▲ 25 (Jun)	△ 23 (Jul)
NV1 - NITROGEN VALVE	▲ 28 (May)	▲ 25 (Jun)	△ 23 (Jul)
SV 1, 2 - SAMPLING VALVE	▲ 28 (May)	▲ 25 (Jun)	△ 23 (Jul)
SP1 - SUMP PUMP	▲ 28 (May)	▲ 18 (Jun)	▲ 2 (Jul)

LEGEND:

1 MR Issued
2 P. O. Placed
3 Procurement on Dock

A-1109

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

August 4, 1976

Program

Martin Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John E. Myers
Mail No. S-0403

Subject: Transmittal of Georgia Tech Program Schedule under MMC Contract RC5-230340

Gentlemen:

Attached herewith are two (2) copies of subject.

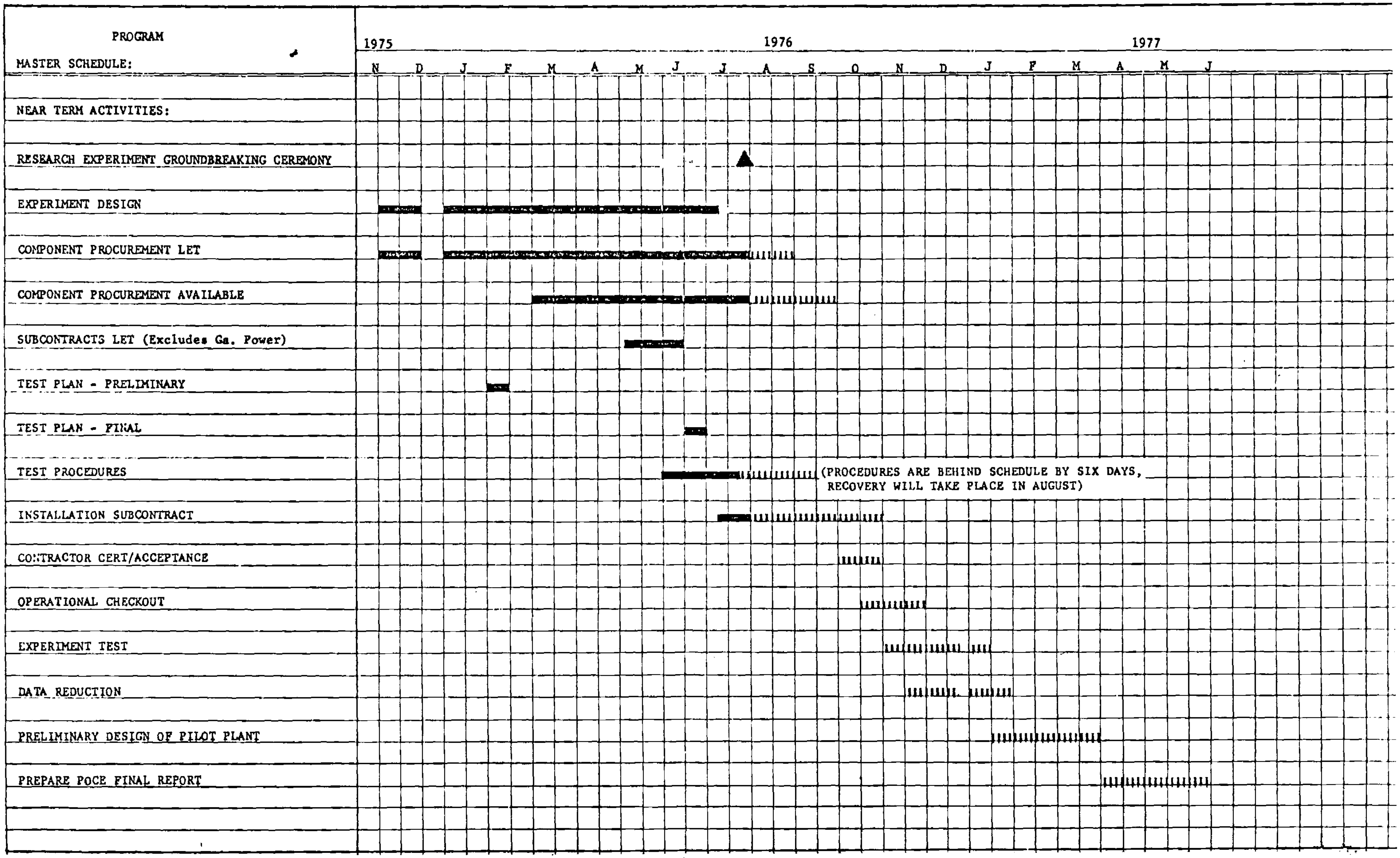
Sincerely yours,

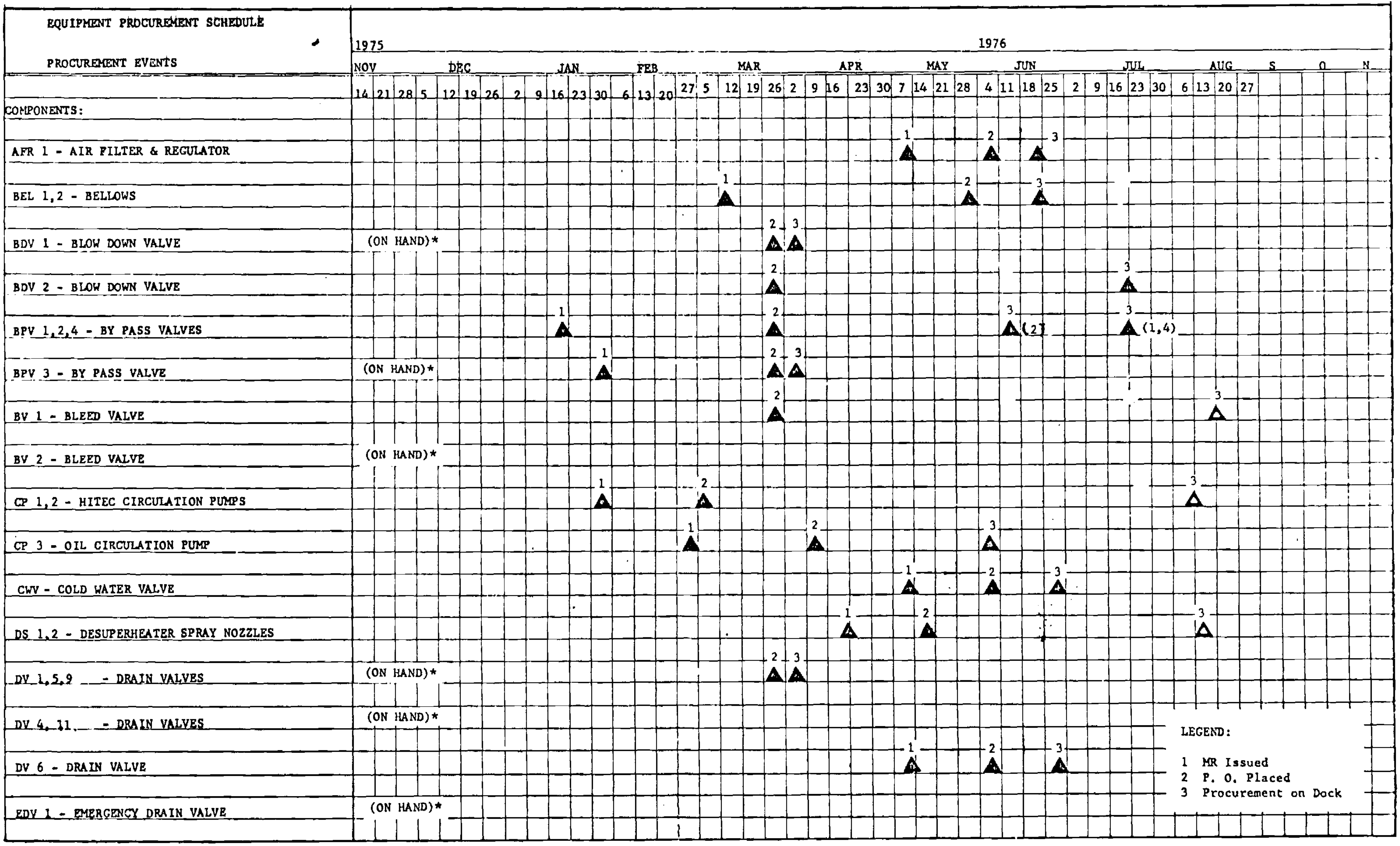
Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

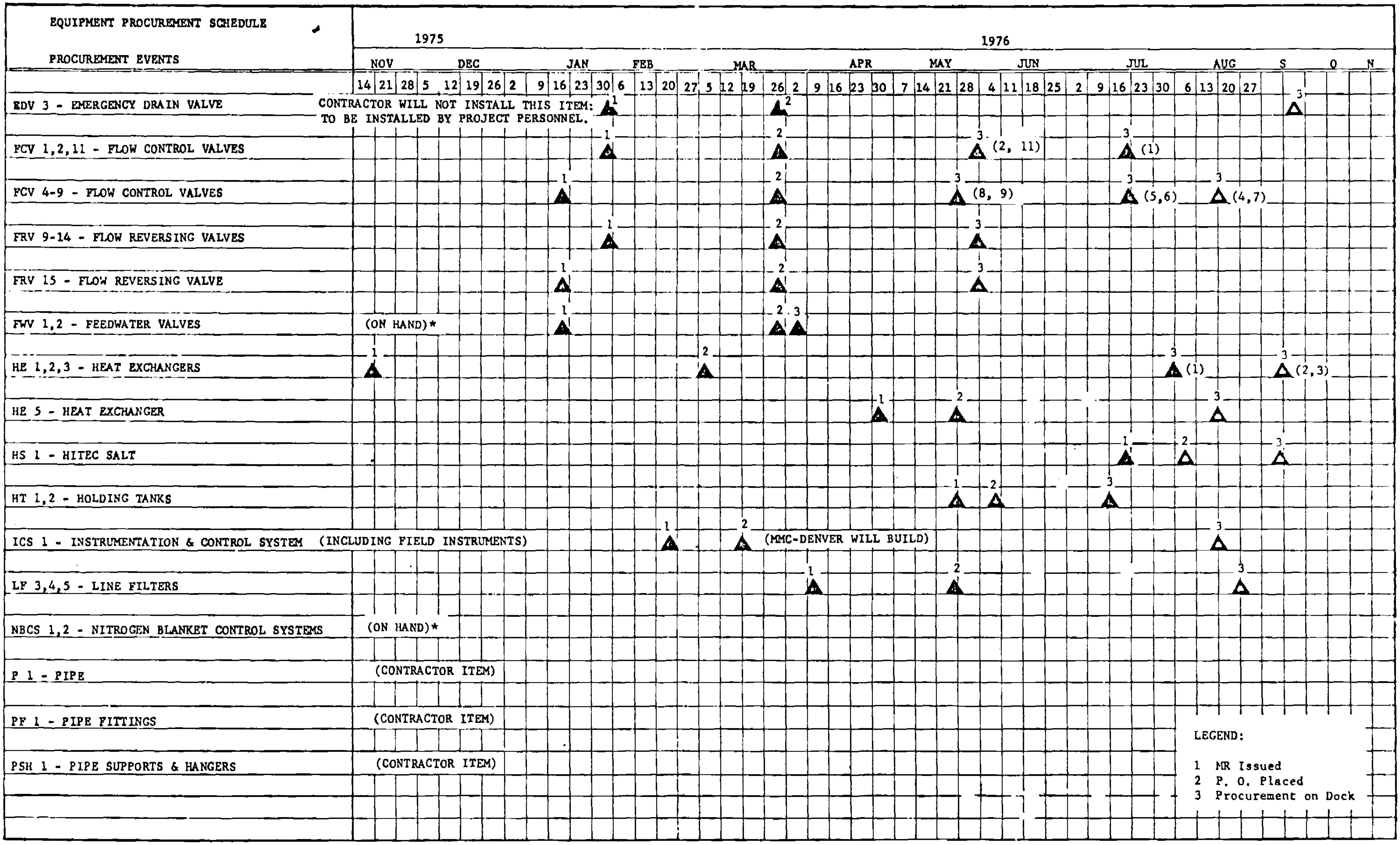
ra

Enclosure: Two (2) copies of Georgia Tech Schedule

cc: Ray Ernest, MMC
Bill Phillips, MMC
Al Becker, GIT
File A-1759 Schedules

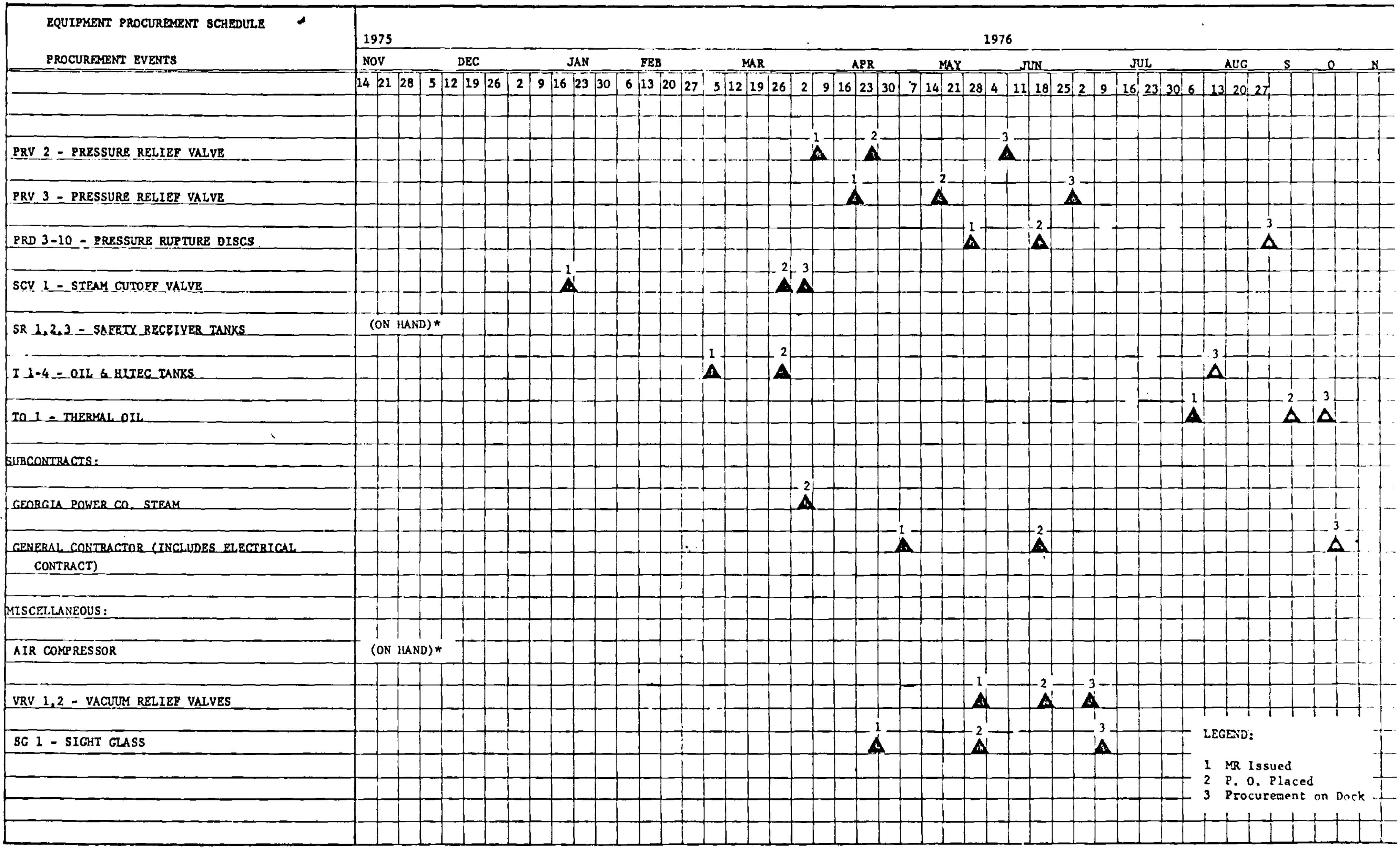

PROGRAM
MASTER SCHEDULE:
1975
1976
1977
N D J F M A M J J A S O N D J F M A M J
NEAR TERM ACTIVITIES:
RESEARCH EXPERIMENT GROUNDBREAKING CEREMONY
EXPERIMENT DESIGN
COMPONENT PROCUREMENT LET
COMPONENT PROCUREMENT AVAILABLE
SUBCONTRACTS LET (Excludes Ga. Power)
TEST PLAN - PRELIMINARY
TEST PLAN - FINAL
TEST PROCEDURES
(PROCEDURES ARE BEHIND SCHEDULE BY SIX DAYS, RECOVERY WILL TAKE PLACE IN AUGUST)
INSTALLATION SUBCONTRACT
CONTRACTOR CERT/ACCEPTANCE
OPERATIONAL CHECKOUT
EXPERIMENT TEST
DATA REDUCTION
PRELIMINARY DESIGN OF PILOT PLANT
PREPARE POCE FINAL REPORT


EQUIPMENT PROCUREMENT SCHEDULE
PROCUREMENT EVENTS
1975
1976
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
S
O
N
14 21 28 5 12 19 26 2 9 16 23 30 6 13 20 27 5 12 19 26 2 9 16 23 30 7 14 21 28 4 11 18 25 2 9 16 23 30 6 13 20 27
COMPONENTS:
AFR 1 - AIR FILTER & REGULATOR
BEL 1,2 - BELLOWS
BDV 1 - BLOW DOWN VALVE
BDV 2 - BLOW DOWN VALVE
BPV 1,2,4 - BY PASS VALVES
BPV 3 - BY PASS VALVE
BV 1 - BLEED VALVE
BV 2 - BLEED VALVE
CP 1,2 - HITEC CIRCULATION PUMPS
CP 3 - OIL CIRCULATION PUMP
CWV - COLD WATER VALVE
DS 1,2 - DESUPERHEATER SPRAY NOZZLES
DV 1,5,9 - DRAIN VALVES
DV 4, 11, - DRAIN VALVES
DV 6 - DRAIN VALVE
EDV 1 - EMERGENCY DRAIN VALVE
(ON HAND)*
(2)
(1,4)
LEGEND:
1 MR Issued
2 P. O. Placed
3 Procurement on Dock



Engineering Experiment Station
Georgia Institute of Technology

Date 7/31/76 Rev. Ltr. F



Engineering Experiment Station
Georgia Institute of Technology

Date 7/31/76 Rev. Ltr. F

Page 4

EQUIPMENT PROCUREMENT SCHEDULE PROCUREMENT EVENTS	1975 NOV			DEC				1976 JAN					FEB				MAR				APR					MAY				JUN				JUL					AUG				S	O	N
	14	21	28	5	12	19	26	2	9	16	23	30	6	13	20	27	5	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25	2	9	16	23	30	6	13	20	27			
ADDITIONAL ITEMS:																																													
AFR2 - AIR FILTER & REGULATOR																										1				2		3													
BDV3 - BLOW DOWN VALVE	(ON HAND)*																																												
BPV 5, 6 - BY PASS VALVES	(ON HAND)*																																												
BV3 - BLEED VALVE	(ON HAND)*																																												
HT3 - HOLDING TANK	(ON HAND)*																																												
NBCS3 - NITROGEN BLANKET CONTROL SYSTEM	(ON HAND)*																																												
NCV1 - NITROGEN CHECK VALVE																													1				2				3								
NV1 - NITROGEN VALVE																													1				2										3		
SV 1, 2 - SAMPLING VALVE																													1				2										3		
SP1 - SUMP PUMP																													1			2		3											

LEGEND:

1 MR Issued
2 P. O. Placed
3 Procurement on Dock

A-1759

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

September 9, 1976

Martin Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John E. Myers
Mail No. S-0403

Subject: Transmittal of Georgia Tech Program Schedule under MMC Contract RC5-230340

Gentlemen:

Attached herewith are two (2) copies of subject.

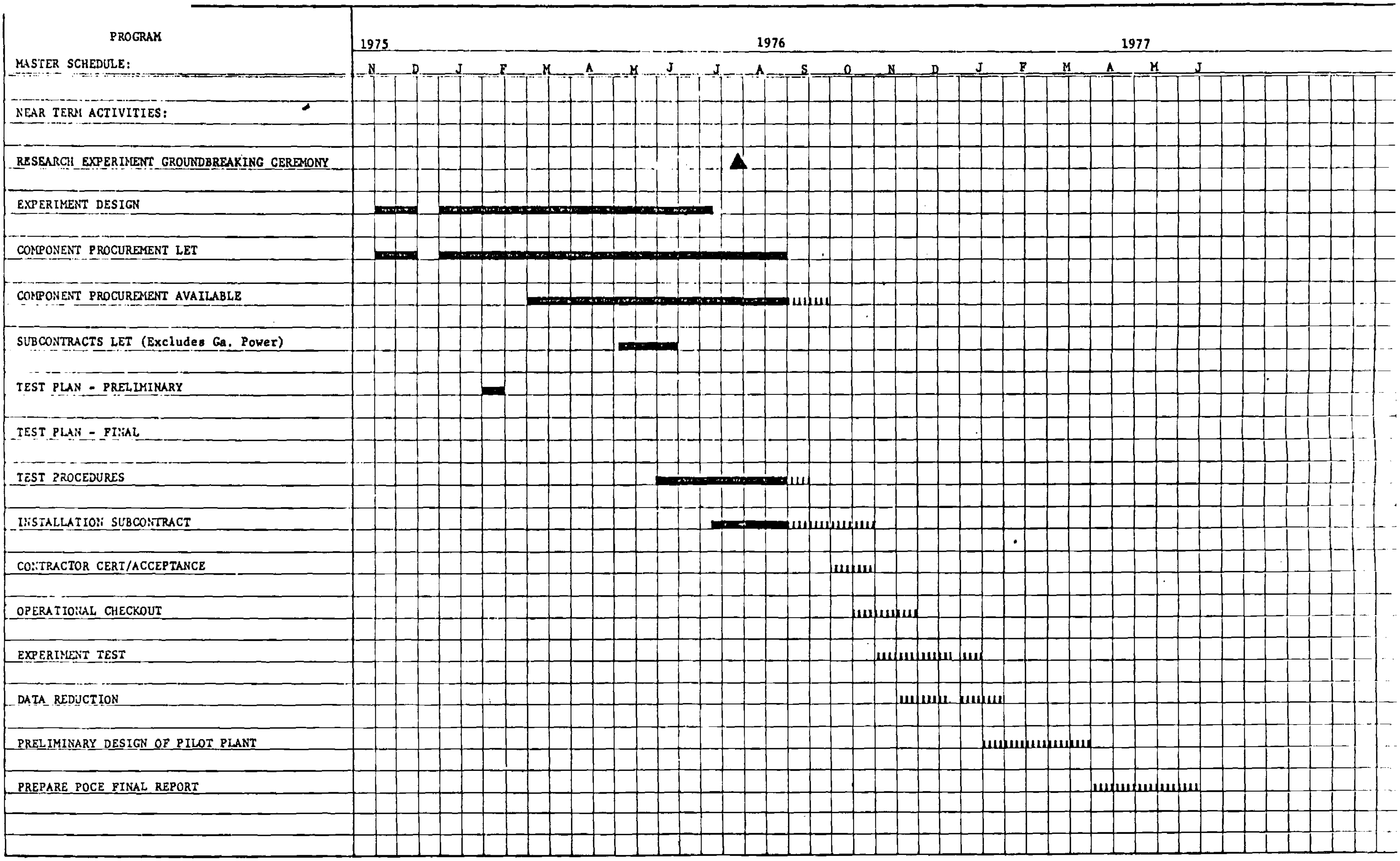
Sincerely yours,

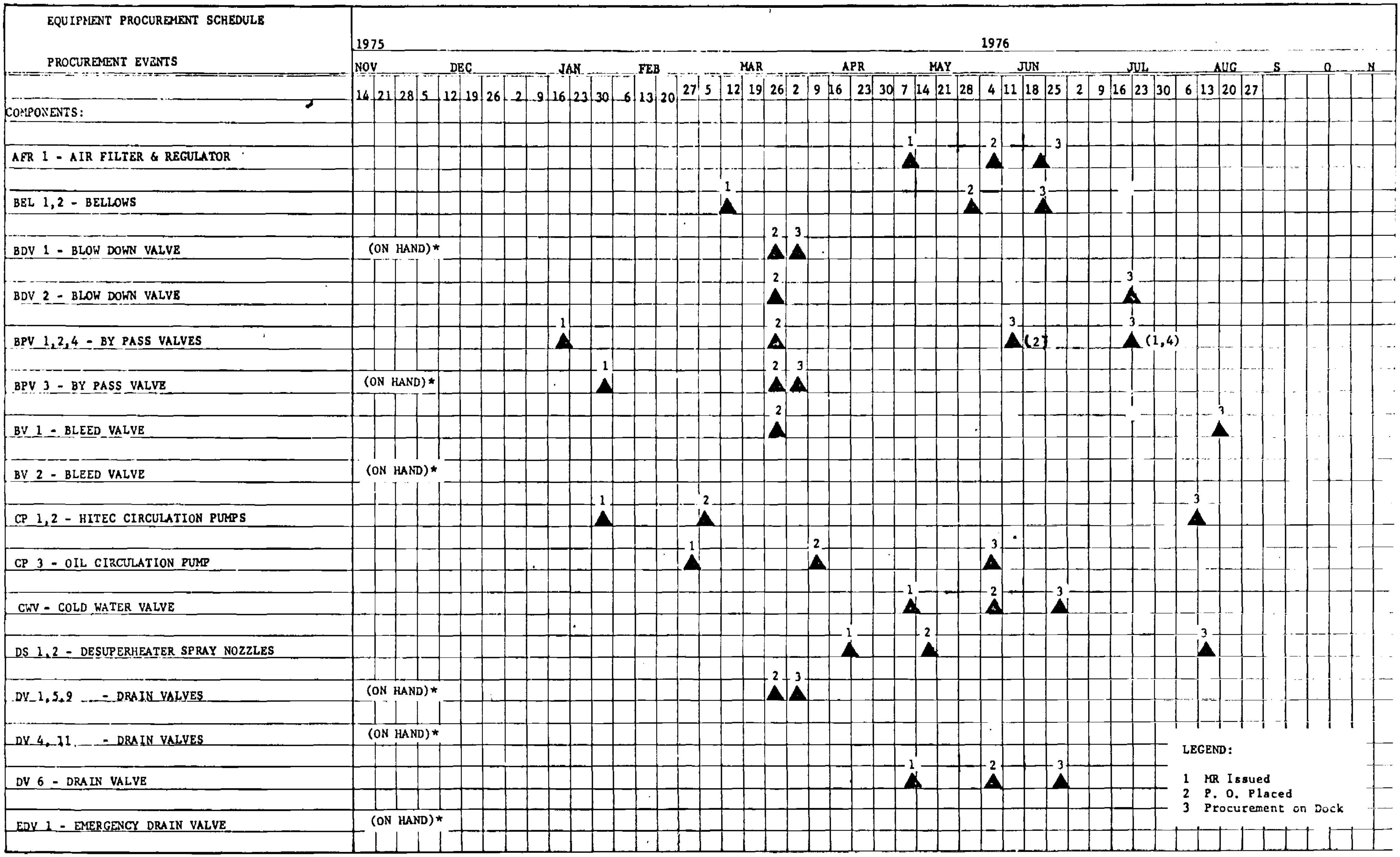
Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

jj

Enclosure: Two (2) copies of Georgia Tech Schedule

cc: Ray Ernest, MMC
Bill Phillips, MMC
Al Becker, GIT ✓
File A-1759 Schedules

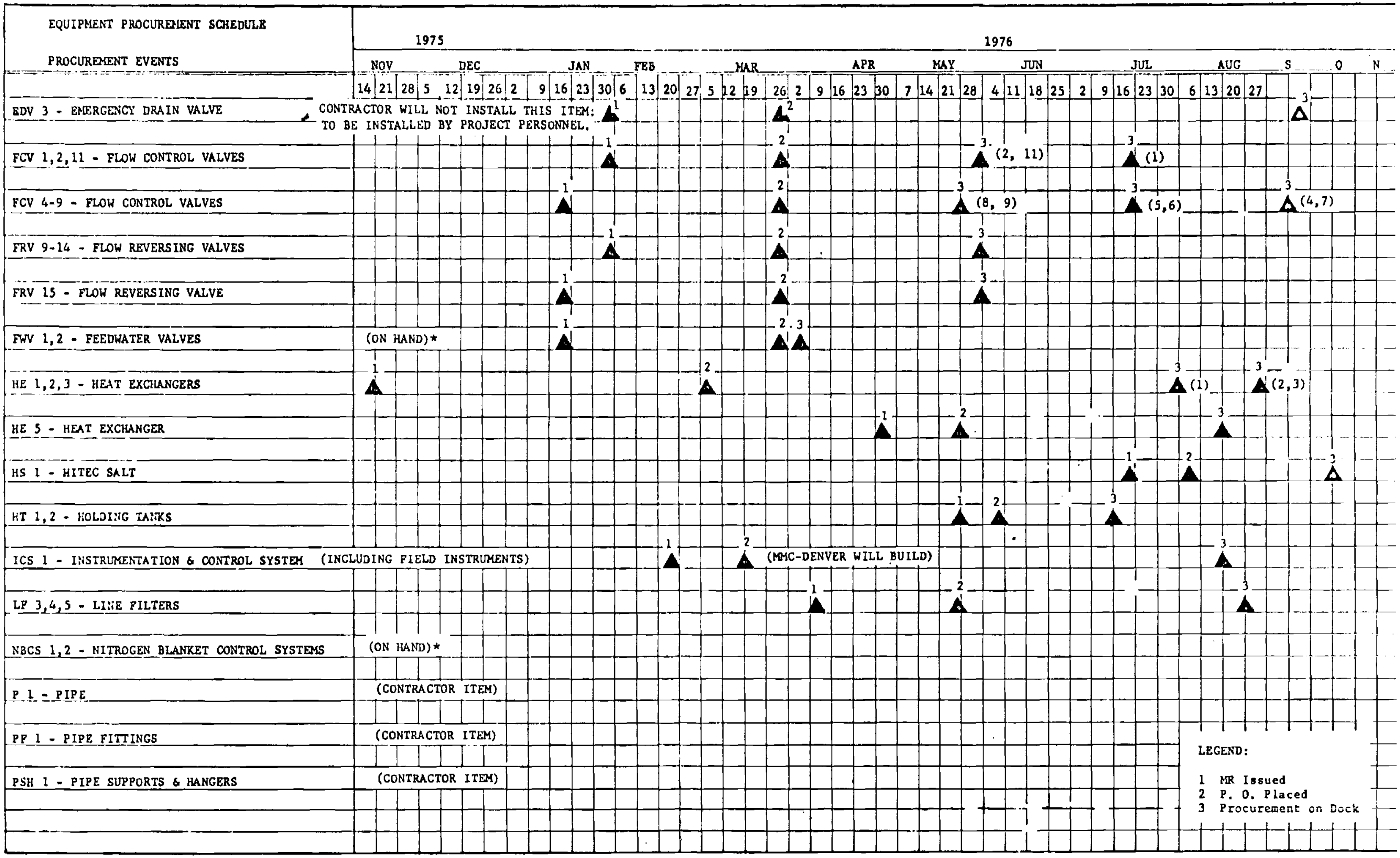

PROGRAM
MASTER SCHEDULE:
1975
1976
1977
N D J F M A M J J A S O N D J F M A M J
NEAR TERM ACTIVITIES:
RESEARCH EXPERIMENT GROUNDBREAKING CEREMONY
EXPERIMENT DESIGN
COMPONENT PROCUREMENT LET
COMPONENT PROCUREMENT AVAILABLE
SUBCONTRACTS LET (Excludes Ga. Power)
TEST PLAN - PRELIMINARY
TEST PLAN - FINAL
TEST PROCEDURES
INSTALLATION SUBCONTRACT
CONTRACTOR CERT/ACCEPTANCE
OPERATIONAL CHECKOUT
EXPERIMENT TEST
DATA REDUCTION
PRELIMINARY DESIGN OF PILOT PLANT
PREPARE POCE FINAL REPORT

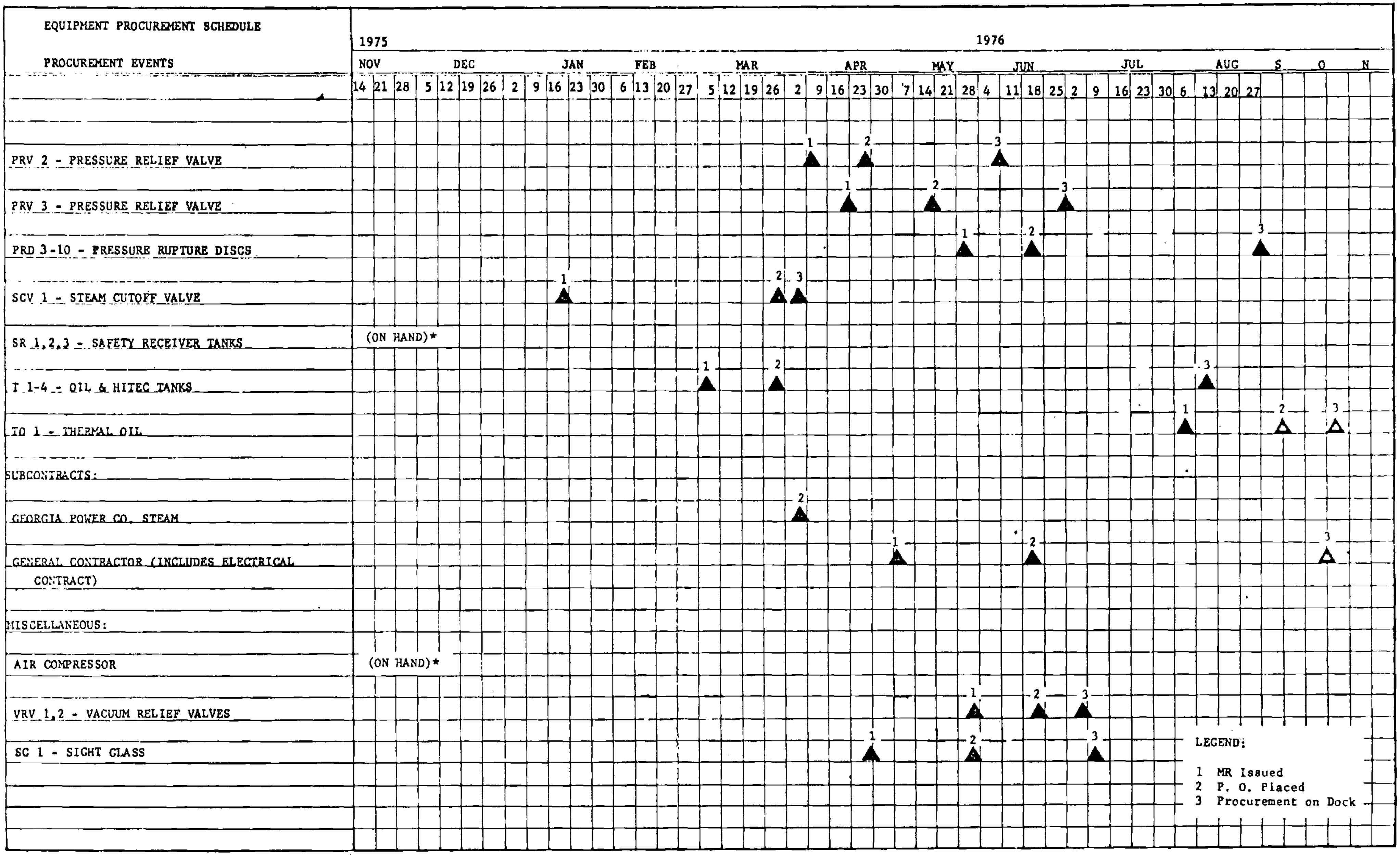


Engineering Experiment Station
Georgia Institute of Technology

Date 8/31/76 Rev. Ltr. G

Page 2


EQUIPMENT PROCUREMENT SCHEDULE
PROCUREMENT EVENTS
1975
1976
NOV DEC JAN FEB MAR APR MAY JUN JUL AUG S O N
14 21 28 5 12 19 26 2 9 16 23 30 6 13 20 27 5 12 19 26 2 9 16 23 30 7 14 21 28 4 11 18 25 2 9 16 23 30 6 13 20 27
EDV 3 - EMERGENCY DRAIN VALVE
CONTRACTOR WILL NOT INSTALL THIS ITEM: TO BE INSTALLED BY PROJECT PERSONNEL.
FCV 1,2,11 - FLOW CONTROL VALVES
(2, 11)
(1)
FCV 4-9 - FLOW CONTROL VALVES
(8, 9)
(5,6)
(4,7)
FRV 9-14 - FLOW REVERSING VALVES
FRV 15 - FLOW REVERSING VALVE
FWV 1,2 - FEEDWATER VALVES
(ON HAND)*
HE 1,2,3 - HEAT EXCHANGERS
(1)
(2,3)
HE 5 - HEAT EXCHANGER
HS 1 - HITEC SALT
HT 1,2 - HOLDING TANKS
ICS 1 - INSTRUMENTATION & CONTROL SYSTEM (INCLUDING FIELD INSTRUMENTS)
(MMC-DENVER WILL BUILD)
LF 3,4,5 - LINE FILTERS
NBCS 1,2 - NITROGEN BLANKET CONTROL SYSTEMS
(ON HAND)*
P 1 - PIPE
(CONTRACTOR ITEM)
PF 1 - PIPE FITTINGS
(CONTRACTOR ITEM)
PSH 1 - PIPE SUPPORTS & HANGERS
(CONTRACTOR ITEM)
LEGEND:
1 MR Issued
2 P. O. Placed
3 Procurement on Dock


EQUIPMENT PROCUREMENT SCHEDULE
PROCUREMENT EVENTS
1975
1976
NOV DEC JAN FEB MAR APR MAY JUN JUL AUG S O N
14 21 28 5 12 19 26 2 9 16 23 30 6 13 20 27 5 12 19 26 2 9 16 23 30 7 14 21 28 4 11 18 25 2 9 16 23 30 6 13 20 27
PRV 2 - PRESSURE RELIEF VALVE
PRV 3 - PRESSURE RELIEF VALVE
PRD 3-10 - PRESSURE RUPTURE DISCS
SCV 1 - STEAM CUTOFF VALVE
SR 1,2,3 - SAFETY RECEIVER TANKS
(ON HAND)*
T 1-4 - OIL & HITEC TANKS
TO 1 - THERMAL OIL
SUBCONTRACTS:
GEORGIA POWER CO. STEAM
GENERAL CONTRACTOR (INCLUDES ELECTRICAL CONTRACT)
MISCELLANEOUS:
AIR COMPRESSOR
(ON HAND)*
VRV 1,2 - VACUUM RELIEF VALVES
SC 1 - SIGHT GLASS
LEGEND:
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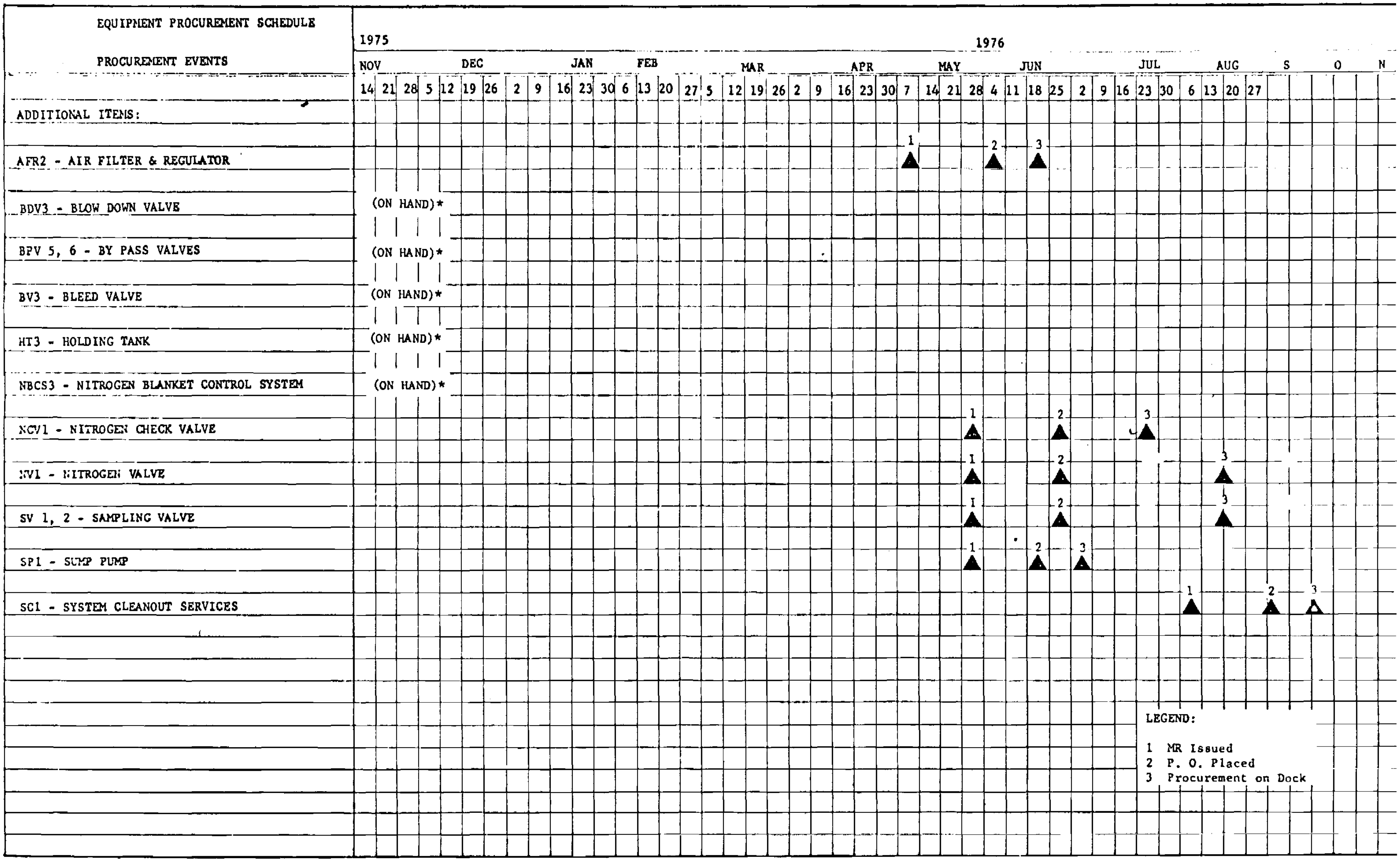

EQUIPMENT PROCUREMENT SCHEDULE
PROCUREMENT EVENTS
1975
1976
NOV DEC JAN FEB MAR APR MAY JUN JUL AUG S O N
14 21 28 5 12 19 26 2 9 16 23 30 6 13 20 27 5 12 19 26 2 9 16 23 30 7 14 21 28 4 11 18 25 2 9 16 23 30 6 13 20 27
ADDITIONAL ITEMS:
AFR2 - AIR FILTER & REGULATOR
BDV3 - BLOW DOWN VALVE
(ON HAND)*
BPV 5, 6 - BY PASS VALVES
(ON HAND)*
BV3 - BLEED VALVE
(ON HAND)*
HT3 - HOLDING TANK
(ON HAND)*
NBCS3 - NITROGEN BLANKET CONTROL SYSTEM
(ON HAND)*
NCV1 - NITROGEN CHECK VALVE
NV1 - NITROGEN VALVE
SV 1, 2 - SAMPLING VALVE
SP1 - SUMP PUMP
SC1 - SYSTEM CLEANOUT SERVICES
LEGEND:
1 MR Issued
2 P. O. Placed
3 Procurement on Dock

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

October 5, 1976

Martin Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John E. Myers
Mail No. S-0403

Subject: Transmittal of Georgia Tech Program Schedule under MMC Contract RC5-230340

Gentlemen:

Attached herewith are two (2) copies of subject.

Sincerely yours,

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

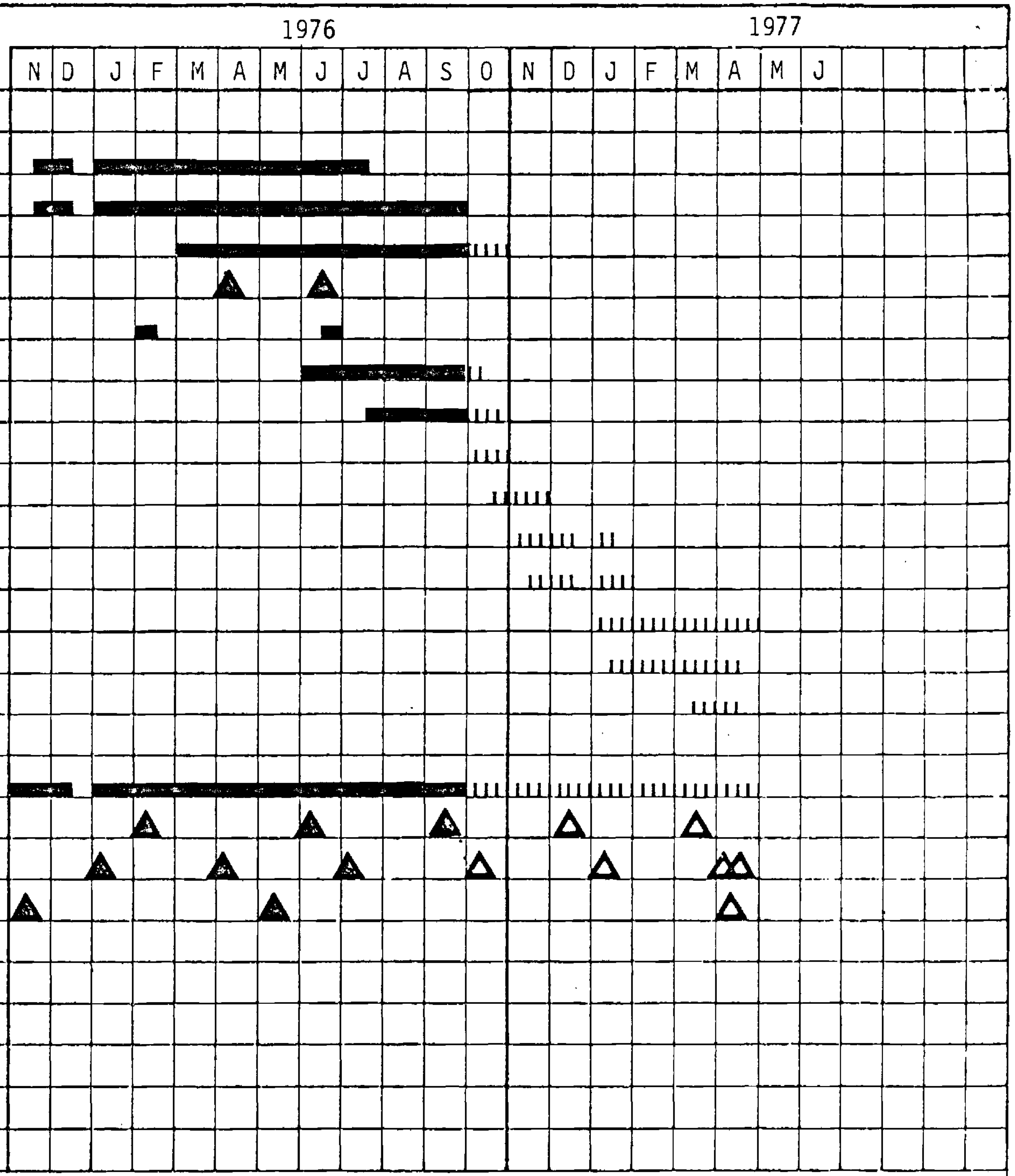
jj

Enclosure: Two (2) copies of Georgia Tech Schedule

cc: Ray Ernest, MMC
Bill Phillips, MMC
Al Becker, GIT
File A-1759 Schedules

PROGRAM SCHEDULE

WBS TASK	TASK DESCRIPTION
422 A	RESEARCH EXPERIMENT DESIGN
423 B	COMPONENT PROCUREMENT LET
423 B	COMPONENT PROCUREMENT AVAILABLE
423 B	SUBCONTRACTS LET
424 B	TEST PLAN
424 B	TEST PROCEDURES
423 B	INSTALLATION SUBCONTRACT
423 B	CONTRACTOR CERT/ACCEPTANCE
423 B	OPERATIONAL CHECKOUT
424 B	EXPERIMENT TEST
424 B	DATA REDUCTION
EC AL	ECONOMIC ANALYSIS
410	PRELIMINARY DESIGN OF PILOT PLANT
410	PREPARE POCE PRELIM DES REPORT
062 C	PROGRAM MANAGEMENT
062 A	PROJECT REVIEWS
TR	TECHNICAL REPORTS
062 A	DESIGN REVIEWS



Engineering Experiment Station
Georgia Institute of Technology

DATE 9/30/76 Rev. H

PROCUREMENT SCHEDULE PROCUREMENT EVENTS	1976 N	D	J	F	M	A	M	J	J	A	S	O
ITEMS RECEIVED DURING SEPTEMBER:												
EDV3 - EMERGENCY DRAIN VALVE				1	2						3	
FCV 4,7 - FLOW CONTROL VALVES			1		2						3	
ITEMS OUTSTANDING:												
HS1 - HEAT TRANSFER SALT									1	2		3
TO1 - HEAT TRANSFER OIL										1	2	3
SC1 - SYSTEM CLEANING										1 2		3
GENERAL CONTRACTOR						1		2				3
MISCELLANEOUS PARTS AND SUPPLIES TO BE USED DURING TESTING OF RESEARCH EXPERIMENT											1 2	3

LEGEND:

1 PR Issued
2 P. O. Placed
3 Procurement on Dock

NOTE: ALL COMPONENTS PROMISED TO THE GENERAL CONTRACTOR ARE NOW ON HAND.

Engineering Experiment Station
Georgia Institute of Technology

DATE 9/30/76 Rev. H

A-1759

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

November 8, 1976

Martin-Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John E. Myers
Mail No. S-0403

Subject: Transmittal of Georgia Tech Program Schedule under MMC Contract RC5-230340

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Program Operations Coordinator
Solar Energy and Materials
Technology Division

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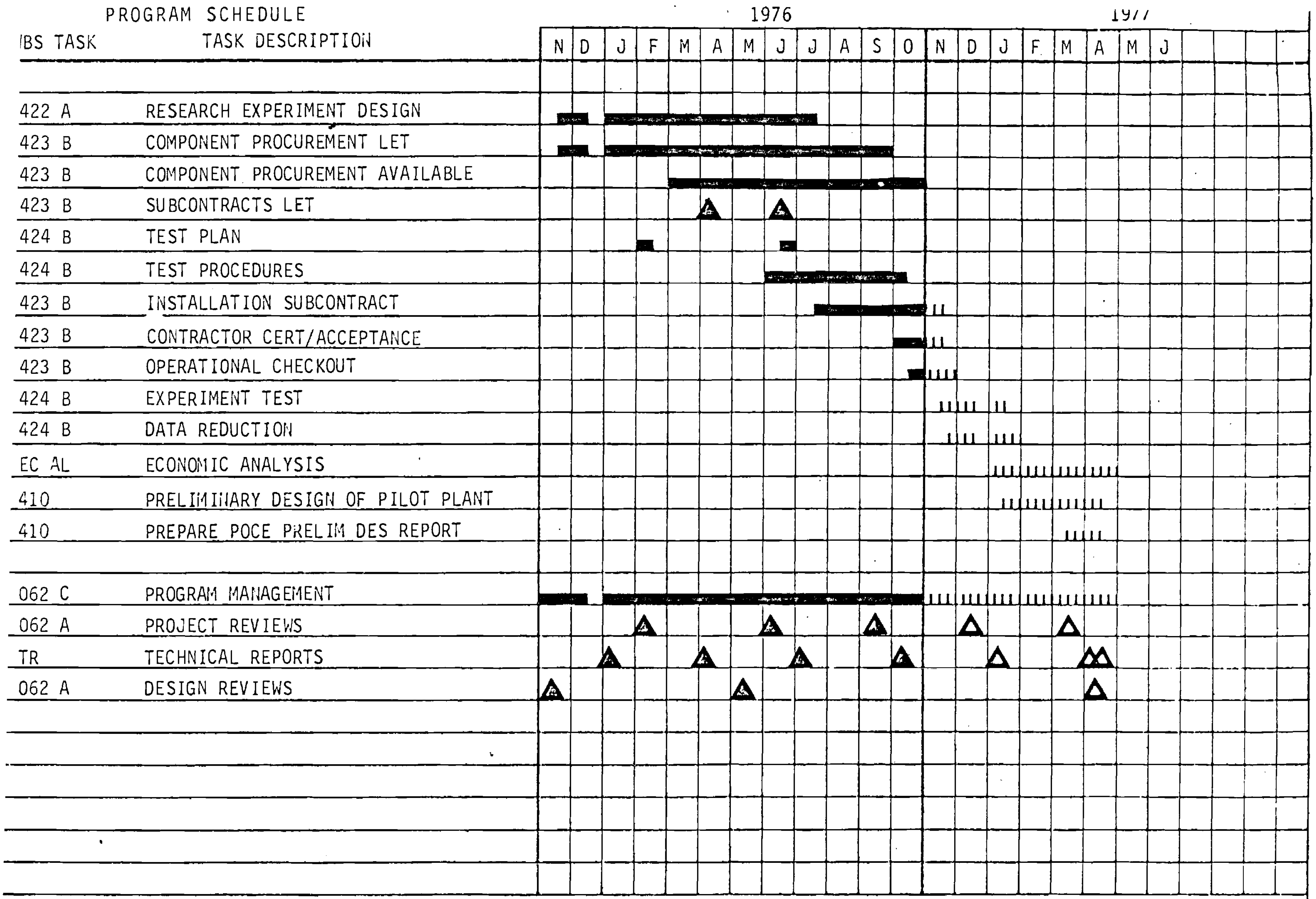
Bill Phillips, MMC
Al Becker, GIT
File A-1759 Schedules



Engineering Experiment Station
Georgia Institute of Technology

DATE 10/31/76 Rev. I
Page 1

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

December 8, 1976

Martin-Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John E. Myers
Mail No. S-0403

Subject: Transmittal of Georgia Tech Program Schedule under MMC Contract RC5-23034

Gentlemen:

Attached herewith are two (2) copies of subject.

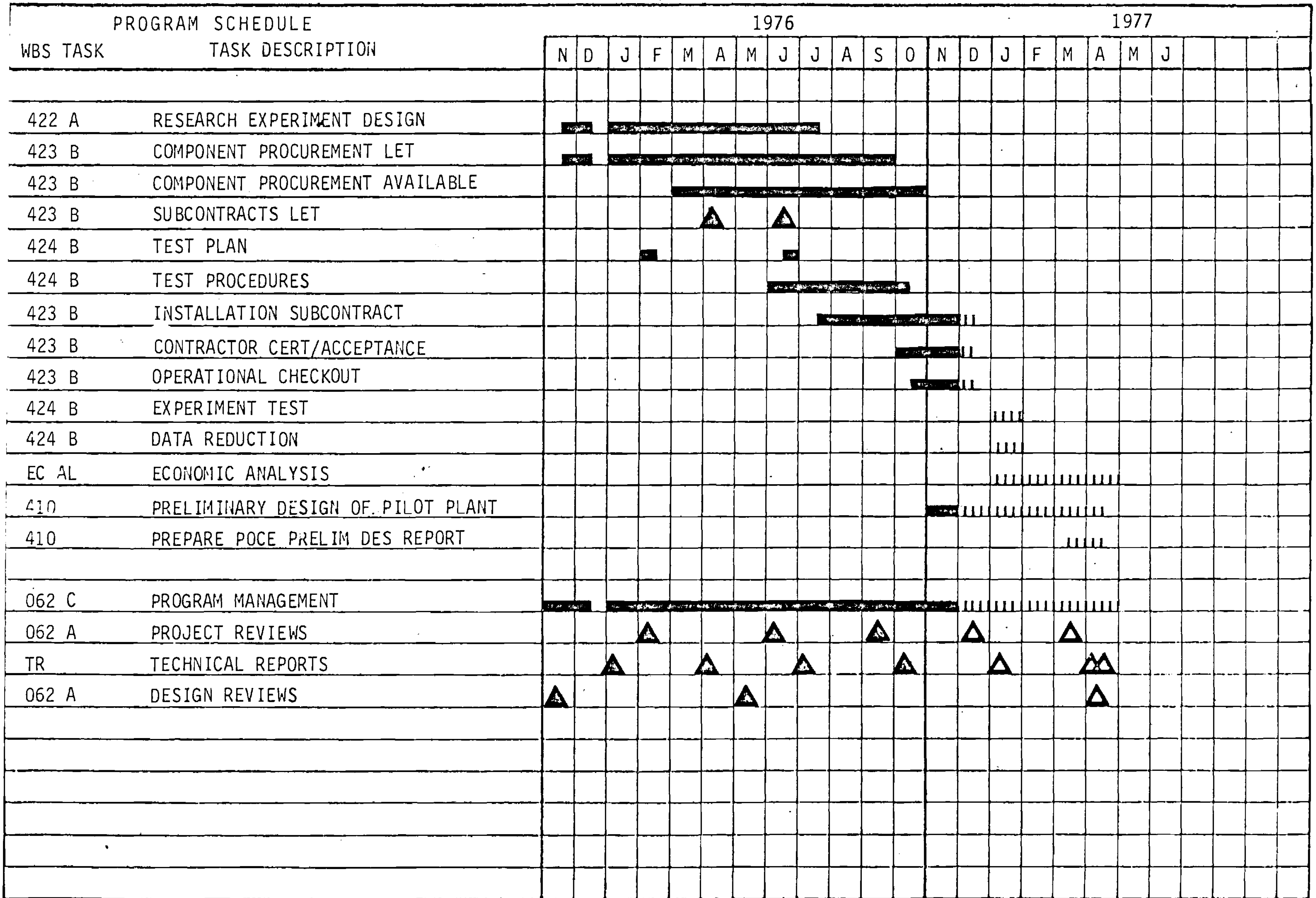
Sincerly yours,

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

gp

Enclosure: Two (2) copies of Georgia Tech Schedule

cc: Ray Ernest, MMC
Bill Phillips, MMC
Al Becker, GIT ✓
File A-1759 Schedules



Engineering Experiment Station
Georgia Institute of Technology

DATE 11/30/76 Rev. J

Page 1

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

January 3, 1977

Martin-Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John E. Myers
Mail No. S-0403

Subject: Transmittal of Georgia Tech Program Schedule under MMC Contract RC5-230340

Gentlemen:

Attached herewith are two (2) copies of subject.

Sincerely,

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

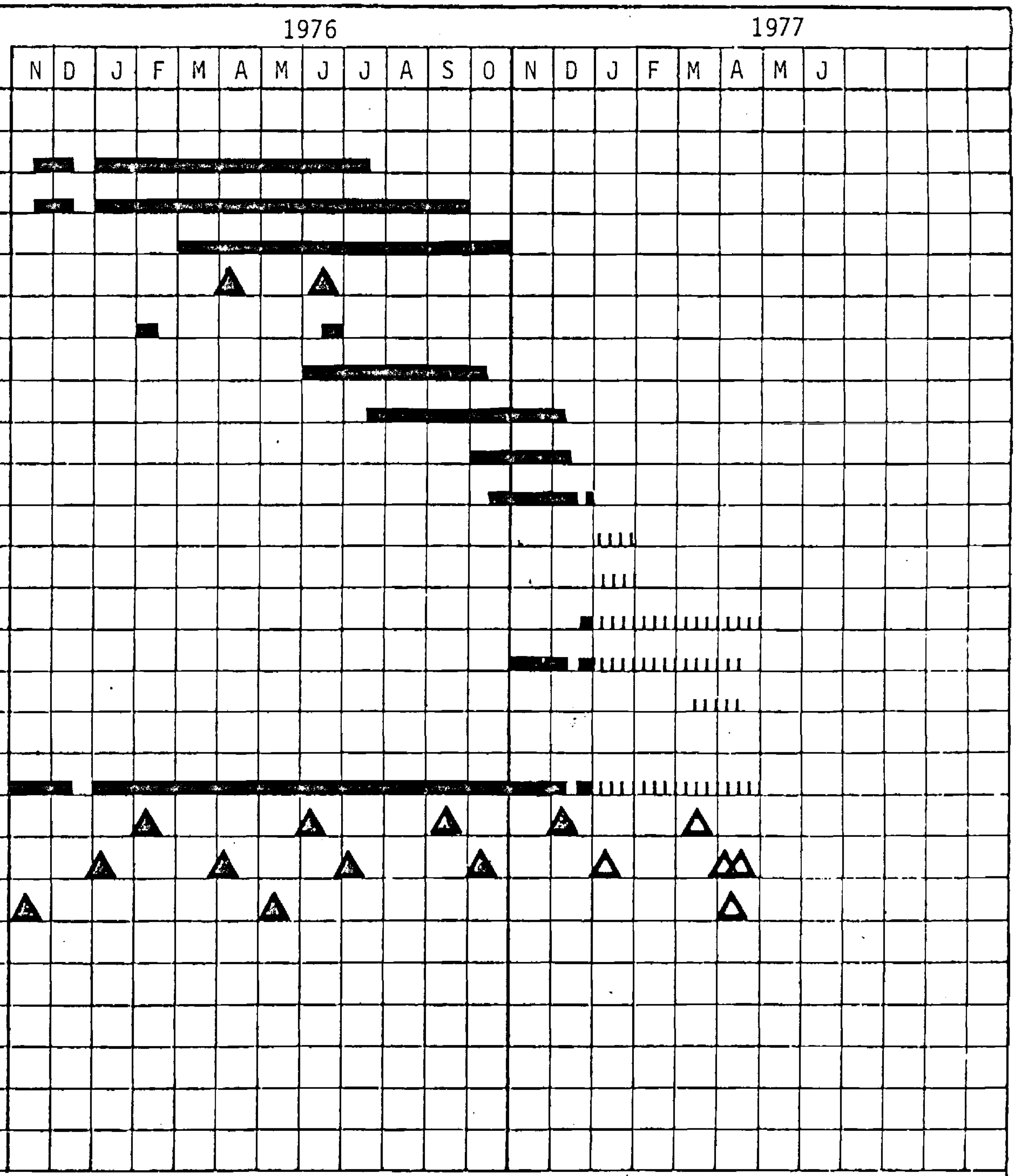
dr

Enclosure: Two (2) copies of Georgia Tech Schedule

cc: Ray Ernest, MMC
Bill Phillips, MMC
Al Becker, GIT
File A-1759 Schedules

PROGRAM SCHEDULE

WBS TASK	TASK DESCRIPTION
422 A	RESEARCH EXPERIMENT DESIGN
423 B	COMPONENT PROCUREMENT LET
423 B	COMPONENT PROCUREMENT AVAILABLE
423 B	SUBCONTRACTS LET
424 B	TEST PLAN
424 B	TEST PROCEDURES
423 B	INSTALLATION SUBCONTRACT
423 B	CONTRACTOR CERT/ACCEPTANCE
423 B	OPERATIONAL CHECKOUT
424 B	EXPERIMENT TEST
424 B	DATA REDUCTION
EC AL	ECONOMIC ANALYSIS
410	PRELIMINARY DESIGN OF PILOT PLANT
410	PREPARE POCE PRELIM DES REPORT
062 C	PROGRAM MANAGEMENT
062 A	PROJECT REVIEWS
TR	TECHNICAL REPORTS
062 A	DESIGN REVIEWS



Engineering Experiment Station
Georgia Institute of Technology

DATE 12/31/76 Rev. K
Page 1

A-1759

ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

February 1, 1977

Martin-Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John E. Myers
Mail No. S-0403

Subject: Transmittal of Georgia Tech Program Schedule under MMC Contract RC5-230340

Gentlemen:

Attached herewith are two (2) copies of subject.

Sincerely,

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

dr

Enclosure: Two (2) copies of Georgia Tech Schedule

cc: Ray Ernest, MMC
Bill Phillips, MMC
Al Becker, GIT
File A-1759 Schedules

PROGRAM SCHEDULE

WBS TASK	TASK DESCRIPTION
422 A	RESEARCH EXPERIMENT DESIGN
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424 B	TEST PLAN
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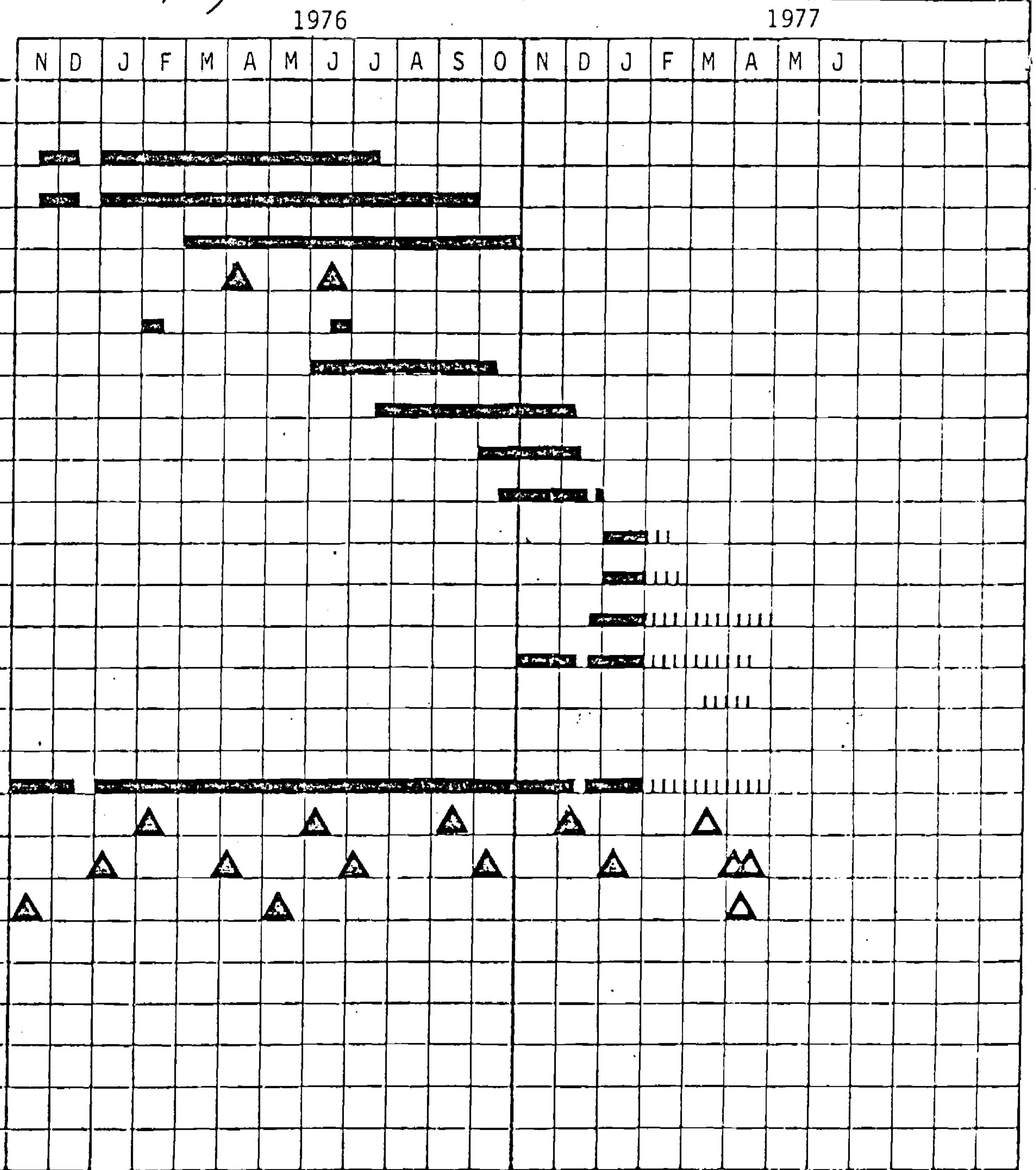
TR	TECHNICAL REPORTS
062 A	DESIGN REVIEWS



Engineering Experiment Station
Georgia Institute of Technology

DATE 1/31/77 Rev. L
Page 1

A-1759

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

March 14, 1977

Martin-Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John E. Myers
Mail No. S-0403

Subject: Transmittal of Georgia Tech Program Schedule under MMC Contract RC5-230340

Gentlemen:

Attached herewith are two (2) copies of subject.

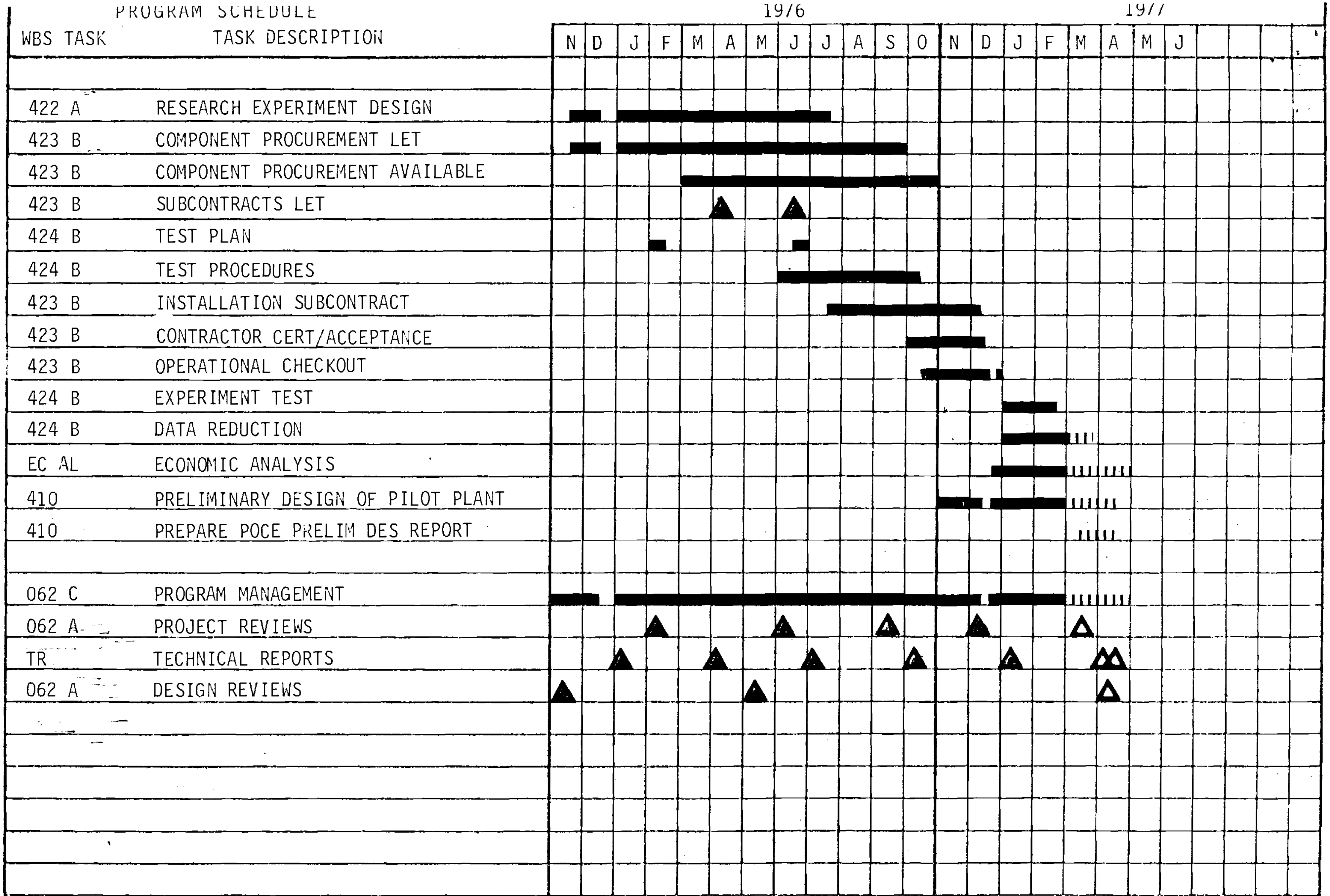
Sincerely,

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

dr

Enclosure: Two (2) copies of Georgia Tech Schedule

cc: Ray Ernest, MMC
Bill Phillips, MMC
L ~~Al~~ Becker, GIT
File A-1759 Schedules



Engineering Experiment Station
Georgia Institute of Technology

DATE 2/28/77

Rev. M
Page 1

IT-1 /⌣ /

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

April 15, 1977

Martin-Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John E. Myers
Mail No. S-0403

Subject: Transmittal of Georgia Tech Program Schedule under MMC Contract RC5-230340

Gentlemen:

Attached herewith are two (2) copies of subject.

Sincerely,

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

dr

Enclosure: Two (2) copies of Georgia Tech Schedule

cc: Ray Ernest, MMC
Bill Phillips, MMC
Al Becker, GIT
File A-1759 Schedules

WBS TASK	TASK DESCRIPTION
422 A	RESEARCH EXPERIMENT DESIGN
423 B	COMPONENT PROCUREMENT LET
423 B	COMPONENT PROCUREMENT AVAILABLE
423 B	SUBCONTRACTS LET
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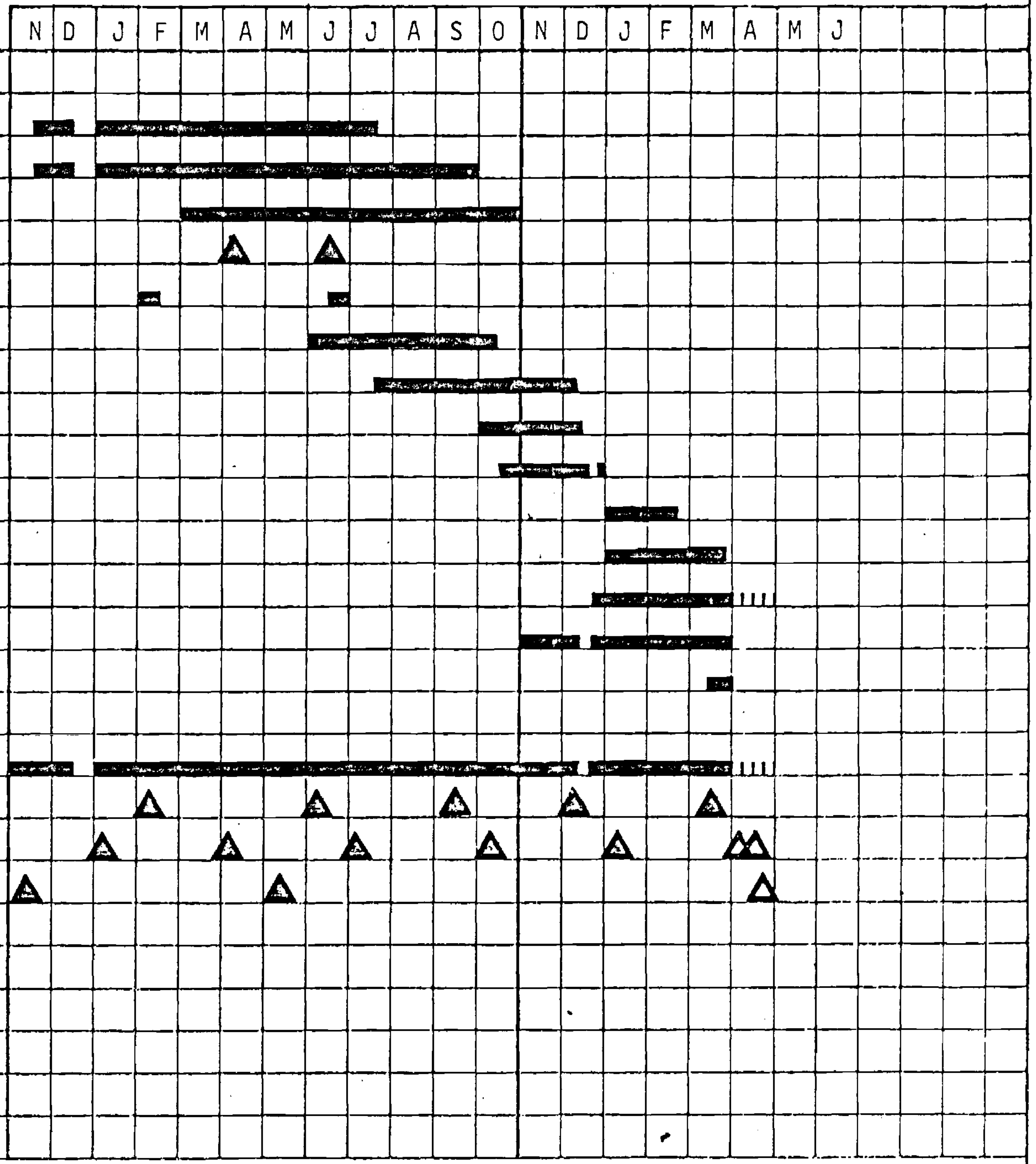


FOR: John E. Myers, Ext. 2332

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

June 30, 1976

Martin Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

Attention: Mr. John E. Myers
Mail No. S-0403

Subject: Transmittal of Georgia Tech Quarterly Report No. 3 under MMC Contract RC5-230340

Gentlemen:

Under separate cover we have transmitted one (1) complete reproducible and one (1) copy of subject.

This completes subject contract requirements for the July 9, 1976 Technical Report under SDRL Item No. 13.

Please send copy to Mr. Ray Ernest.

Sincerely yours,

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

jw

Enclosures: One (1) reproducible and one (1) copy of Georgia Tech Quarterly Report No. 3

cc: Mr. Ray Ernest, MMC Denver
Mr. Al Becker, GIT
A-1759 Commu.

CENTRAL RECEIVER SOLAR THERMAL POWER SYSTEM
(PHASE I)

Quarterly Report

SECTION VI

THERMAL STORAGE SUBSYSTEM

Authors:

Ralph F. Altman
Steve H. Bomar, Jr.
Charles A. Murphy
John E. Myers

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

VI. THERMAL STORAGE SUBSYSTEM

A. INTRODUCTION

During the period covered by this Quarterly Report, April 1976 through June 1976, several of the major activities that were in progress during the previous quarter were concluded. The completed activities are: (1) the detailed design of the Thermal Storage Subsystem Research Experiment, (2) specification preparation and order placement for all major components for the Research Experiment, and (3) selection of the construction contractor and award of the contract. In addition, the Research Experiment Final Test Plan was written, a study that lead to the storage media selection was completed and preparation of the Research Experiment Test Procedures was begun.

1. Thermal Storage Subsystem Research Experiment

The detail design of the Research Experiment was completed during this quarter. The design effort included:

- Layout and analysis of all of the steam, feedwater, molten salt and oil piping.
- Specification and selection of pumps and valves.
- Review and approval of heat exchanger designs.
- Review and approval of storage media tank designs.
- Review and approval of control console and control system components.

Orders for all system components have been placed and the oil circulation pump, the oil bypass cooler, all the flow reversing valves, four flow control valves and one pressure relief valve have been received. The construction of the heat exchangers and storage media tanks is proceeding on schedule.

Thermxchanger, Inc., the subcontractor that is supplying the heat exchangers, has ordered and received all components and materials required for fabrication except gaskets, sealing rings and the mesh separator for the evaporator. All of the sub-assemblies of the two molten salt heat exchangers are complete and final assembly of these units will begin early in July. Sub-assembly fabrication for the two oil heat exchangers is scheduled to begin in early July. J. J. Finnigan Industries, Inc., will supply the tanks for the Research Experiment. All tank components have been delivered to J. J. Finnigan and fabrication is 30 percent complete.

A request for quotation for the construction of the Research Experiment was issued on May 6, 1976. The quotation request included general specifications, piping drawings, code requirements, electrical requirements, desuperheater detail drawings and construction date requirements. Responses to the request were opened on June 7. After reviewing the respondents quotes and qualifications, Broyles and Broyles, Inc., Atlanta Division, was selected as the contractor. Construction of the Research Experiment at Plant Yates, a Georgia Power Company facility, is scheduled to begin on or about July 12, 1976.

Selection of the storage media was also made during this quarter. The hydrocarbon oil will be EXXON heat transfer oil, HT-43. The molten salt will be heat transfer salt, HTS. The by weight chemical composition of the salt is 53 percent potassium nitrate, 40 percent sodium nitride and 7 percent sodium nitrate. Orders for both storage media will be placed early in July.

2. Other Program Activities

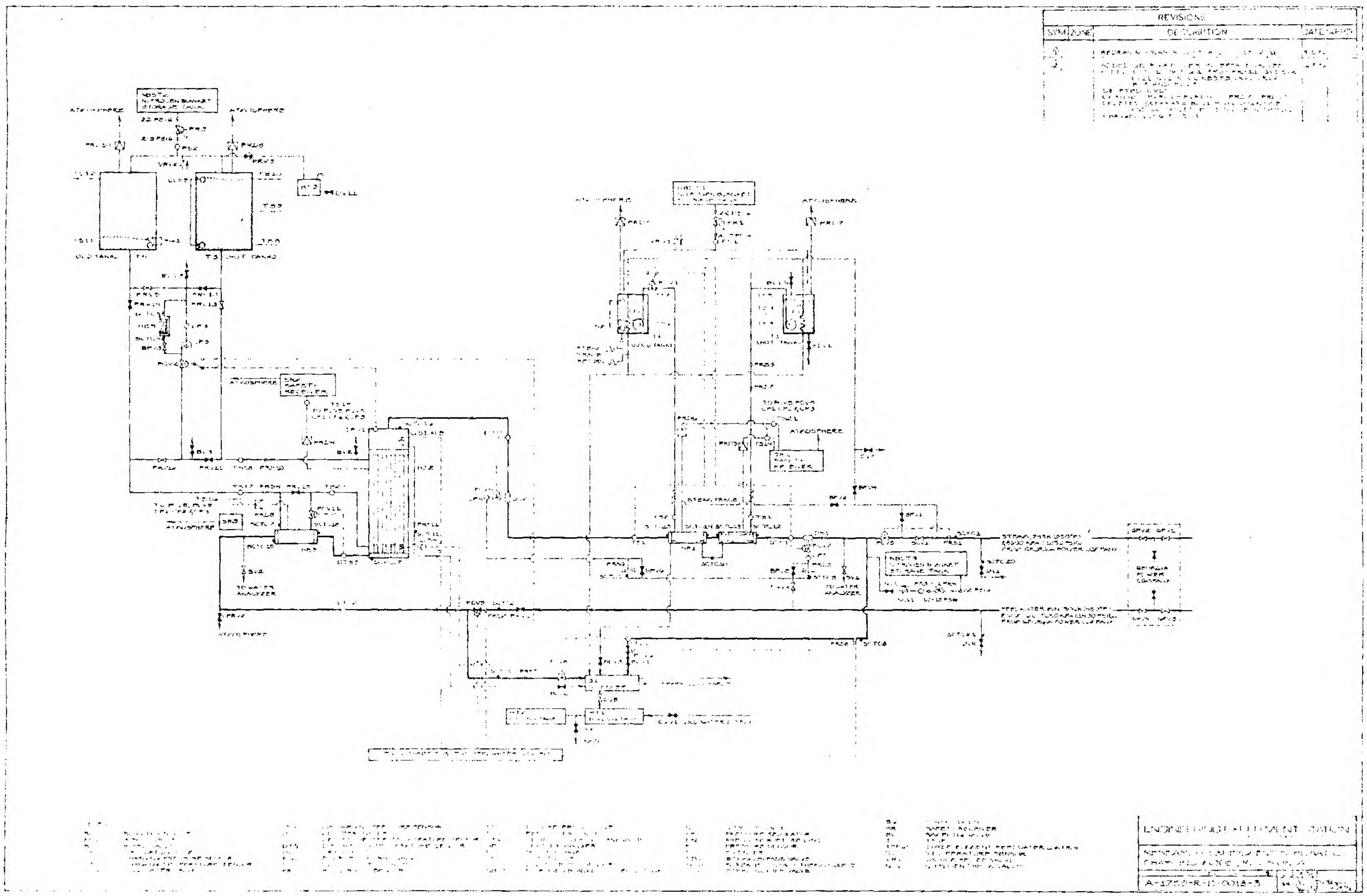
Two program reviews were conducted during this quarter: (1) the Quarterly Program Review and Detailed Design Review on May 20 and 21, (2) the Semi-Annual Program Review on June 2. The Research Experiment Final Test Plan was written during this quarter, the detailed test procedures were defined, and writing of the procedures was begun.

B. THERMAL STORAGE SUBSYSTEM RESEARCH EXPERIMENT DETAILED DESIGN

The major program efforts this quarter were the completion of the detailed design of the Research Experiment and the preparation of the Final Test Plan and Detailed Procedures. The test plan will be discussed in the next section of this report. The design effort, which was concentrated in the first half of the report period, is covered in this section.

1. Research Experiment Detailed Schematic

Some modifications to the Research Experiment design have been made since the last Quarterly Report was published. These changes have all been incorporated into the detailed schematic shown in Figure VI-1. Generally, the changes simplify system operation or improve system safety. A nitrogen cover gas system


REVISIONS
SYM
ZONE
DESCRIPTION
ATMOSPHERE
HOT TANK

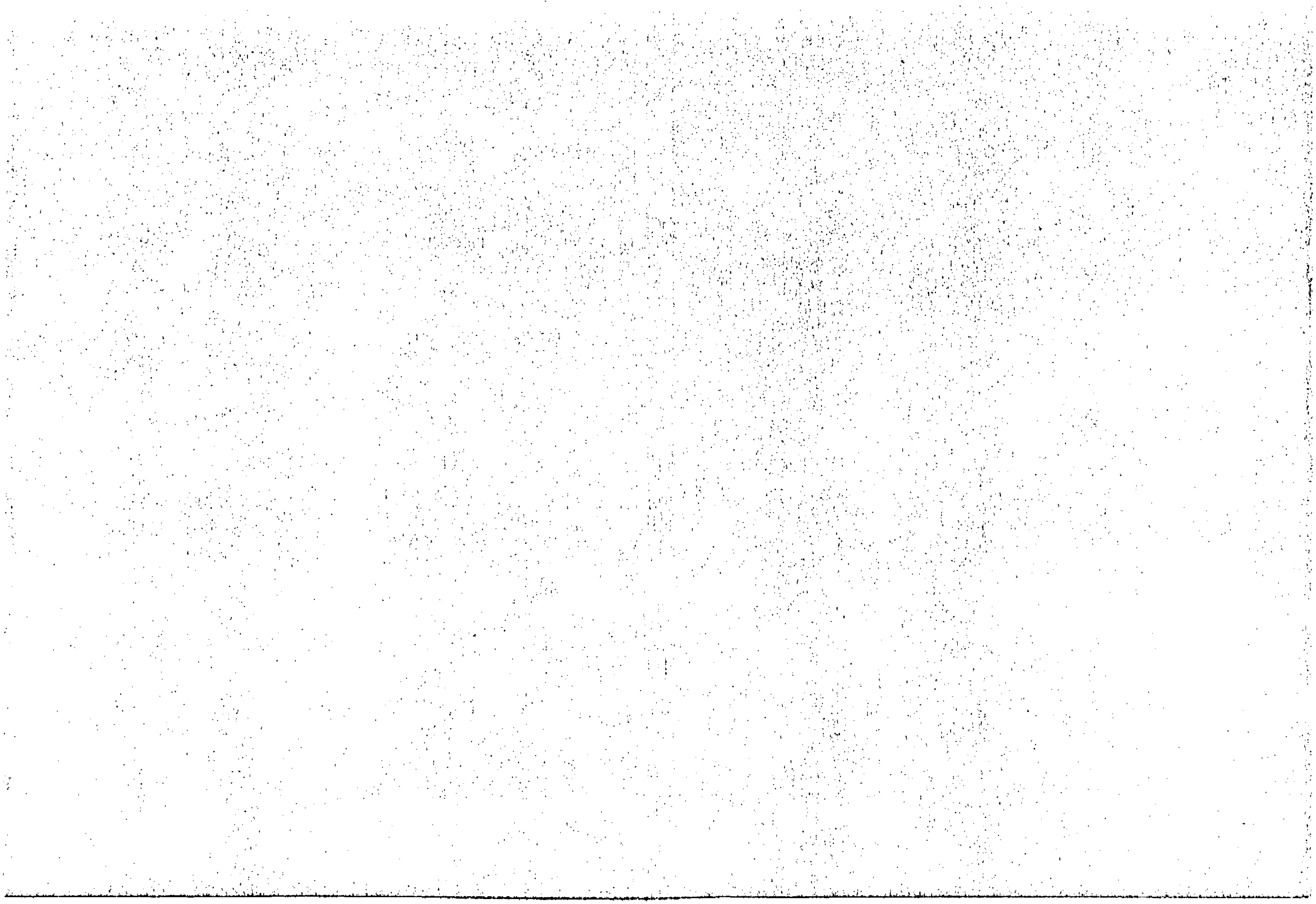


Figure VI-1. Schematic of Thermal Storage System Research Experiment.

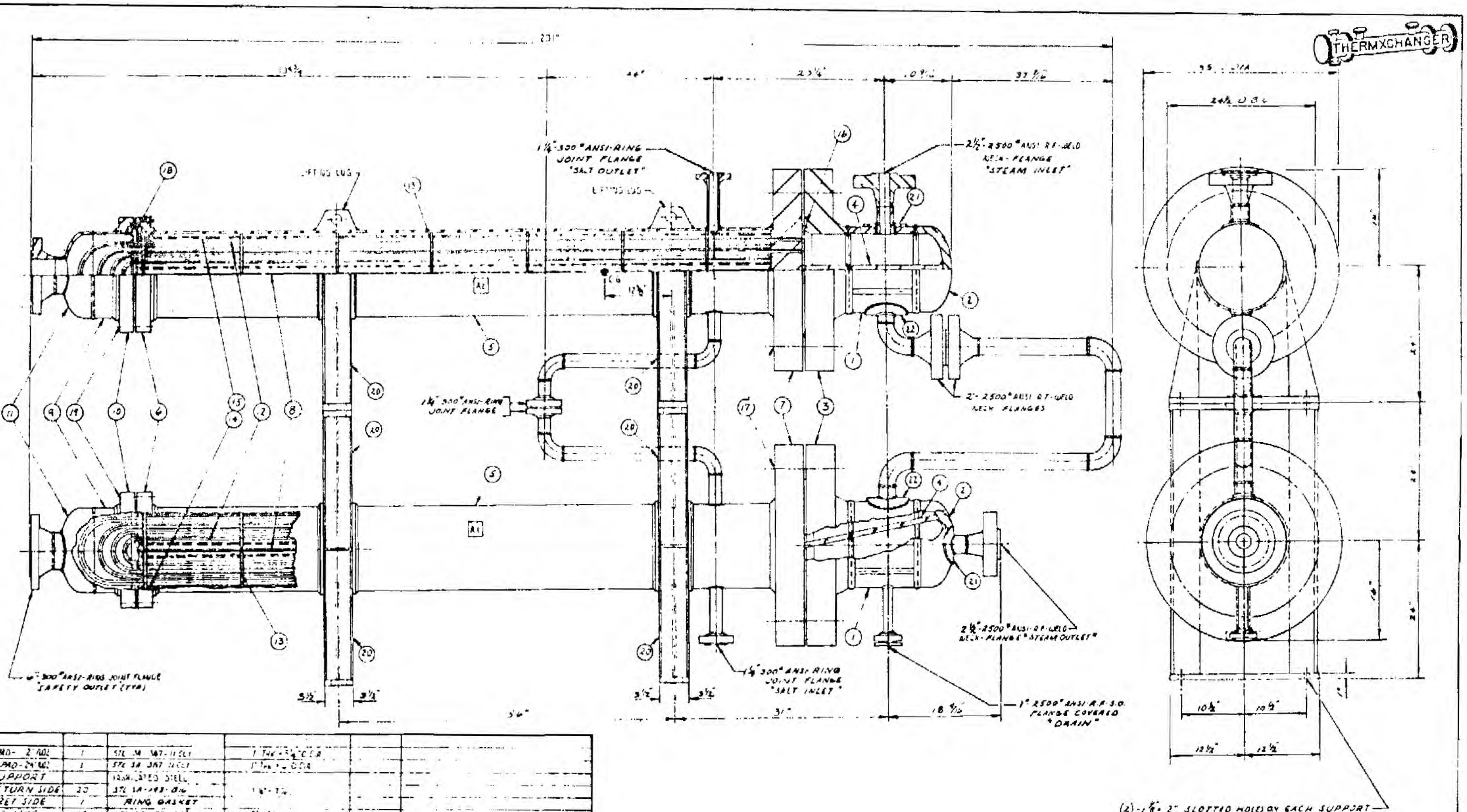
has been added to the main steam line. When the Research Experiment is not being operated, the steam and water side of the heat exchangers and piping will be drained. The pressure will then be reduced to near atmospheric and a 10 psig nitrogen line into the main steam line will be opened. The nitrogen line will have a check valve in it to prevent backflow into the nitrogen cover gas system. The cover gas will minimize the formation of condensate in the piping and heat exchangers overnight and eliminate oxygen contamination of feedwater and steam during system start-up.

Two piping changes have been made to make it easier to drain condensate from the steam lines. The low point in the steam line into the Research Experiment has been moved so that this line can now be drained through FCV6. The separate drain line that contained the blowdown valve, BDV1 was eliminated. The drain valve, DV10, on the head of HE1 has been changed to a blowdown valve and the corresponding drain line is now connected to the silencer. Steam and feedwater sampling lines have been added. Samples of feedwater into the system and condensate out of the system will be drained off through SV2. The samples will be cooled and a conductivity measurement will be made. Additional tests will measure sample pH, oxygen content and nitrate content. Steam samples will be collected through SV1 during charging and discharging. The steam will be condensed and then analysed in the same manner as the condensate and feedwater.

Approximately 20 surface contact thermocouples have been added to the schematic. These sensors will monitor temperatures that are important for safety reasons or necessary for system analysis. It was recognized at the beginning of the program that these thermocouples would be needed, but their location was dependent on the details of the design, and so the locations were not specified until the design was largely complete. These thermocouples are designated as SCTC's on the schematic.

2. Heat Exchangers

The heat transfer parameters, surface areas, number of tubes, etc., for the Research Experiment heat exchangers were reported in the last Quarterly Report. Thermxchanger, Inc., completed the detailed design of the exchangers during this quarter and some of the design features will influence the heat exchangers performance and the operation of the Research Experiment. These features are shown in Figures VI-2 to VI-4, the outline drawings of the heat exchangers.



PART NO	DESCRIPTION	QUAN. FOR ONE UNIT	MATERIAL	SIZE	DWG NO	REMARKS
22	REINFORCING PAD - 2" NOZ	1	STL SA 387-11 CL1	1 THK × 5¾ O.D.A.		
21	REINFORCING PAD - 2½" NOZ	1	STL SA 387-11 CL1	1" THK × ... O.D.A.		
20	SHELL SUPPORT		FABRICATED STEEL			
19	BOLTS, RETURN SIDE	20	STL SA-193-B16	1⅛" - 7¾		
18	GASKET, RET SIDE	1	RING GASKET			
17	BOLTS, E/E SIDE	14	STL SA-193-B16	2" DIA		
16	GASKET, E/E SIDE	1	S.STEEL "C" RING	⅜" DIA		
15	TIE RODS	8	STEEL	½ DIA		
14	SPACERS	90	STL SA 213-T11	¾ O.D. × .2 ...		
13	BAFFLES	30	STL SA 387-11 CL1	⅜ THK		
12	TUBES	60 U's	STL SA 213-T11	¾ O.D. × ...		
11	COVER, RET BONNET	1	STL SA 387-11 CL1	...		
10	FLANGE, BONNET RET	1	STL SA ... F11	14" 300# ANSI RING JOINT FLG		
9	RETURN BONNET	1	STL SA 335-P11	...		
8	PASS RIB, SHELL	1	STL SA 387-11 CL1	⅜ THK		
7	TUBE SHEET	1	STL SA 182-F11	5⅝ THK × 35 O.D.		
6	FLANGE, SHELL	1	STL SA 182-F11	14" 300# ANSI RING JOINT FLG		
5	SHELL	1	STL SA 335-P11	...		
4	PASS RIB, E-E BONNET	1	STL SA 387-11 CL1	1 THK		
3	FLANGE E-E BONNET	1	STL SA 182-F11	3⅞" THK × 35 O.D.		
2	COVER E-E BONNET	1	STL SA 387-11 CL1	...		
1	ENT/EXIT BONNET	1	STL SA 387-11 CL1	...		

NOTES:

1. CONSTRUCTED IN ACCORDANCE WITH THE ASME CODE SECTION VIII-DIVISION I
2. HEAT TREAT ENTRANCE/EXIT BONNETS
3. 100 % X RAY ENTR/EXIT NOZZLES
4. ROLL & STRENGTH WELD TUBES TO TUBE SHEETS
5. [illegible]

SHELL	510	705	9535
TUBE	1420	3835	9975
PRESS	DESIGN	TEST	TEMP

TOTAL DRY WEIGHT 15,070 lb
TOTAL WET WEIGHT 15,480 lb

NO. 1410 TYPE SUX - 2
SUPERHEATER-DESUPERHEATER HE-1

THERMXCHANGER, INC.
OAKLAND CALIFORNIA

GAO TECH.
SCALE NONE
DATE 05-08-76
E-1:00

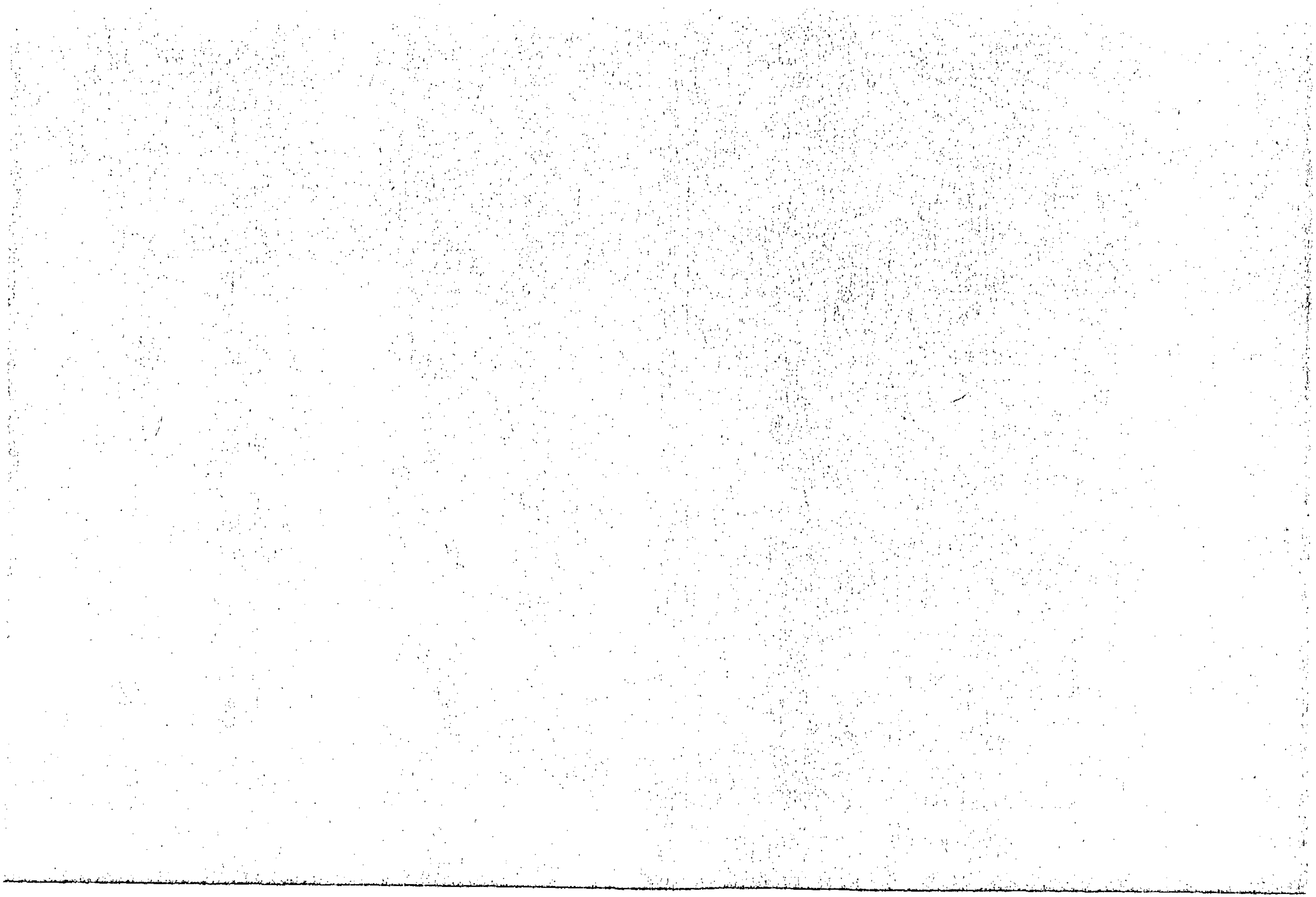
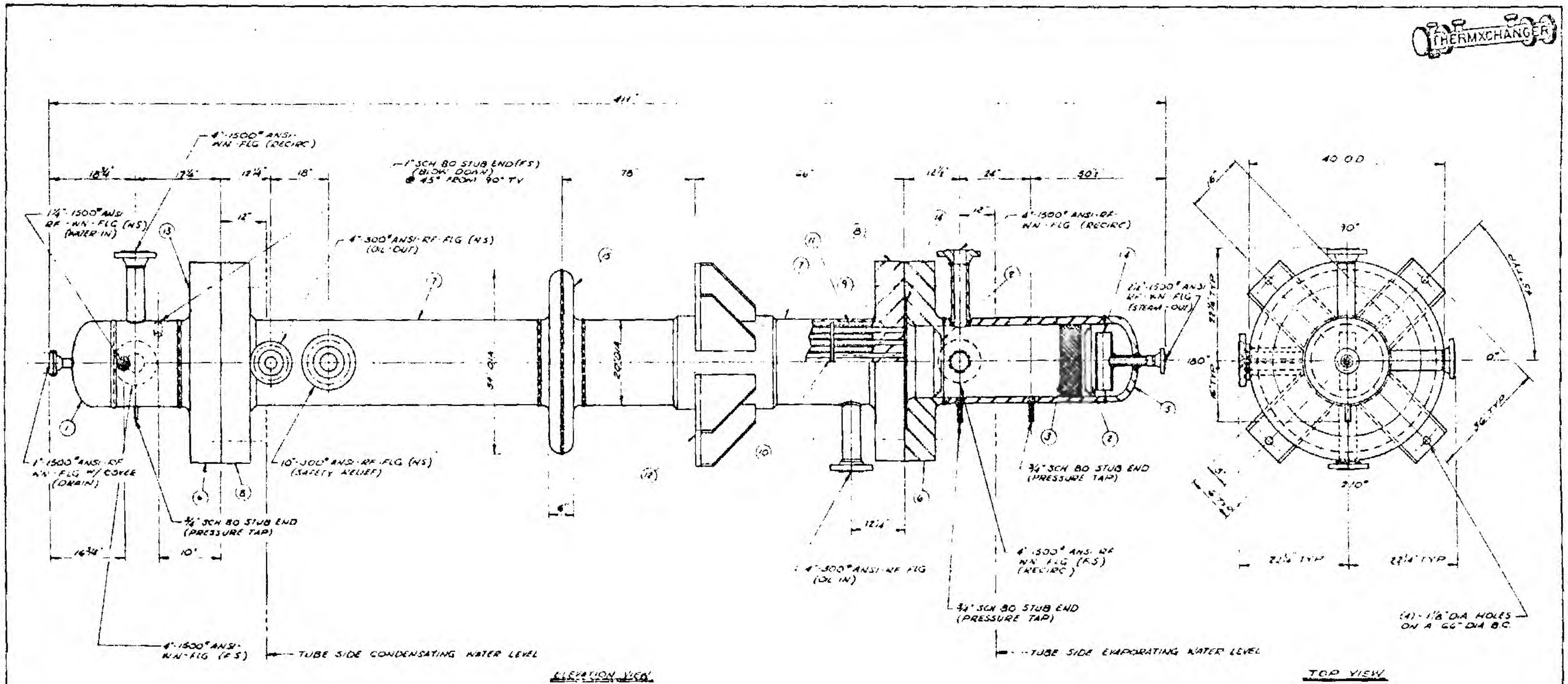


Figure VI-2. Drawing of Superheating-Desuperheating Heat Exchanger HE2.



NOTE
1. CONSTRUCTED IN ACCORDANCE WITH THE ASME CODE SECT 8, DIV 1
2. POSTWELD HEAT TREAT INLET AND OUTLET BONNETS
3. 100% X RAY
4. DRY WEIGHT = 18656 lbs.
5. CLEAN TO SPECIFICATIONS

ITEM	DESCRIPTION	QTY	MATERIAL	SIZE	DWG	REMARKS
15	EXPANSION JOINT	1	STEEL			
14	O RING	2	S STEEL	300 SERIES		
13	BOLTING		STL SA 193 B7			NUTS STL SA 194 2H
12	SHELL SUPPORTS	1	STL SA 36			
11	TIE RODS		STEEL			
10	BAFFLES		STL SA 36			
9	TUBING		STL SA 179 (FINNED)	¾ O.D. - 14 BWG		19 FINS PER INCH
8	TUBE SHEETS	2	STL SA 181 2			
7	SHELL	1	STL SA 53 B OR 104	20 O.D. - ⅜" WALL		
6	BONNET FLANGES	2	STL SA 181 2			
5	OUTLET BONNET	1	FAB STL SA 515-70			
4	DRY PIPE	1	STL SA-53 B			
3	SCREEN	1	STL FLEX MESH			
2	CONE	2	STEEL			
1	INLET BONNET	1	FAB STL SA 515 70			

PRESS	DESIGN	TEST	TEMP
TUBE	1420	2140	650
SHELL	300	450	650

A REVISED

"ERDA - TYPE STX - 1 PASS HEAT EXCHANGER (HE-2)

THERMXCHANGER, INC.
OAKLAND CALIFORNIA

CUST Gesdyne Tech.

SCALE NONE

DATE 3 24 75

DWG NO. E-1110

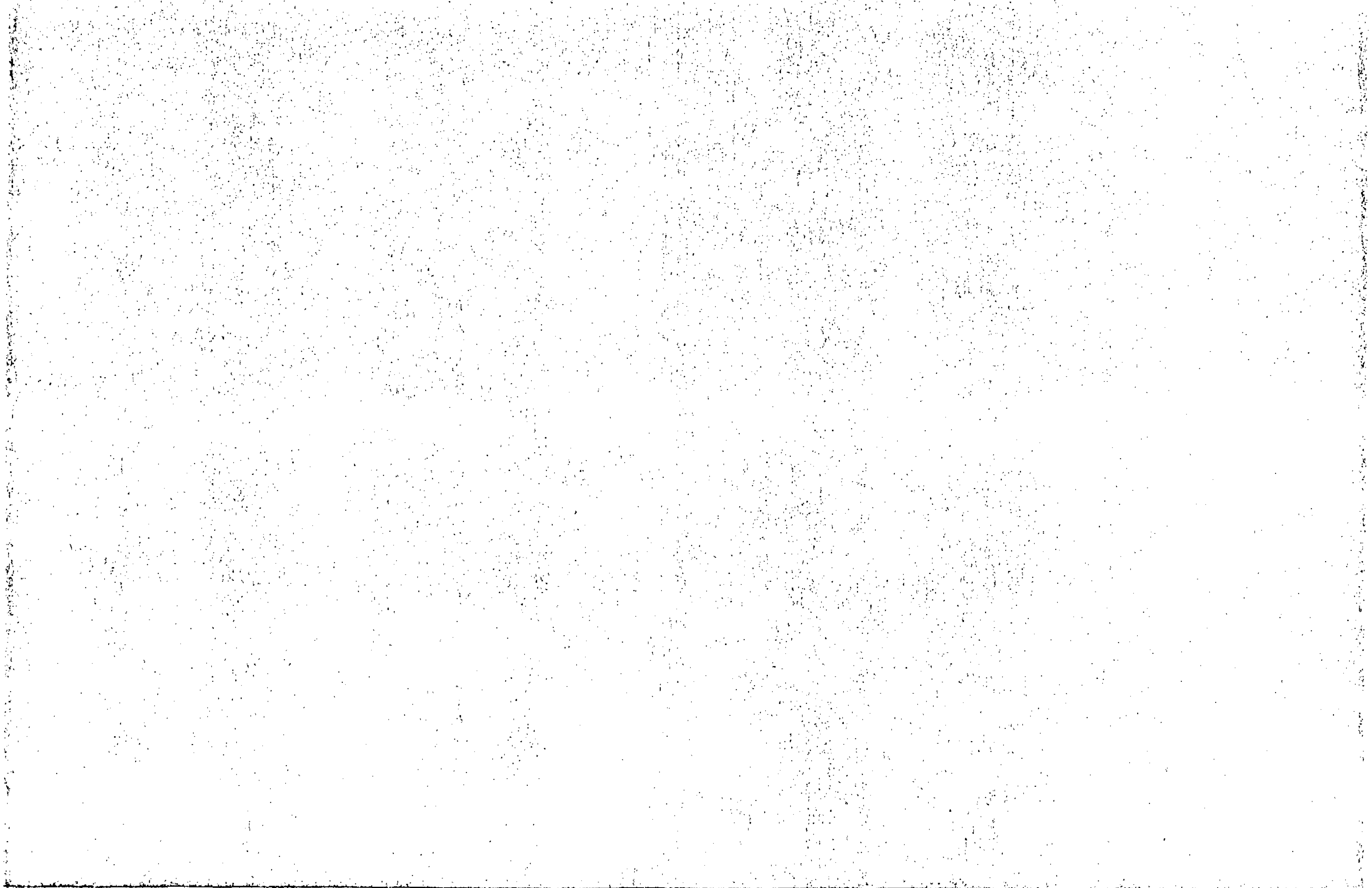
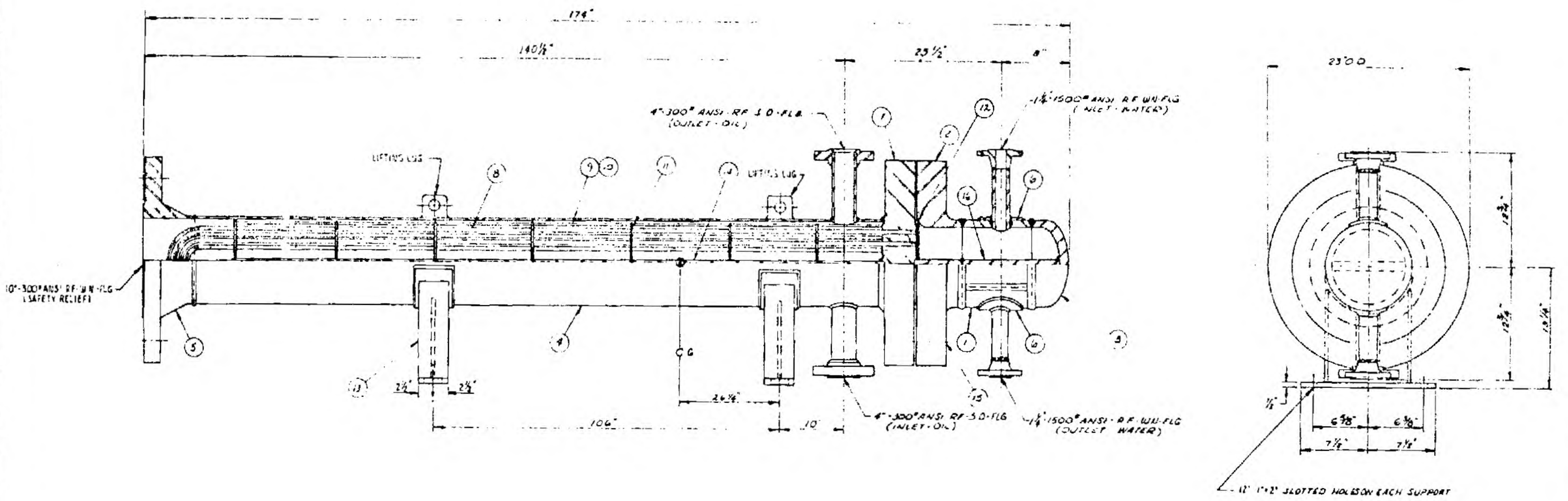


Figure VI-3. Drawing of Condensing-Evaporating Heat Exchanger HE2.



NOTE
1. CONSTRUCTED IN ACCORDANCE WITH THE ASME CODE SECT 8, DIV 1
2. POSTWELD HEAT TREAT ENTR-EXIT BONNET
3. 100% X-RAY ENTR EXIT BONNET
4. ROLL & STRENGTH WELD TUBES TO TUBE SHEET
5. [illegible]

THIS DRAWING IS THE PROPERTY OF THERMXCHANGER INC. OAKLAND CALIFORNIA

ITEM	DESCRIPTION	QTY	MATERIAL	SIZE	DWG	REMARKS
16	PASS RIB	1	STEEL SA 285-C	⅜" THK	E-1129	
15	BOLTING E-E BONNET	16	STL SA 193-B7	1¼" TLC		NUT SA 194 2H
14	SHELL PASS RIB	1	STEEL SA 285-C	⅜" THK	D-1662	
13	SHELL SUPPORT	2	FABR STEEL		E-1130	
12	C-RING	1	S STEEL "C" RING	¼" DIA		
11	BAFFLES	20	STEEL SA 36	3/16" THICK	D-1662	
10	TIE RODS	8	STEEL	⅜" DIA	D-1662	
9	SPACERS	60	STEEL	⅝ O.DIA × 22 BWG	D-1662	
8	TUBING	30 U	FINNED STEEL SA 179	¾ O.D. × 14 BWG	E-1131	19 FINS PER INCH
7	TUBE SHEET	1	STL SA-181-2	5 THK × 23 O.DIA	E-1131	
6	REINFORCING PAD	2	STL SA-515-70	½" THK × 3" O.DIA	E-1129	
5	SHELL FLANGE	1	STL SA 181-2	10" 300# ANSI W.N. FLANGE	E-1130	
4	SHELL	1	STL SA 538 OR 106	10" SCH 30 PIPE	E-1130	
3	ENTR-EXIT COVER	1	STL SA 515-70	5⅝" WALL × 10¾" O.D. S.E. HD	E-1129	
2	ENTR-EXIT BONNET FLG	1	STL SA-181-2	2⅛" THK × 23 O.D.	E-1129	
1	ENTR-EXIT BONNET	1	FABR STEEL SA-515-70	⅝" WALL × 10¾" O.DIA	E-1129	

DRY WEIGHT 2476 lb.
WET WEIGHT 2542 lb.

PRESS	DESIGN	TEST	TEMP
SHELL	300	450	600
TUBE	1420	2130	650

5	REVISED		
4	REVISED FOR APPROVAL		
3	REVISED FOR APPROVAL		
MARK	REVISION		DATE

#3012 - TYPE SUX HEAT EXCHANGER (HE-3)

THERMXCHANGER, INC.
OAKLAND CALIFORNIA

GEORGIA TECH
DWG E-1109

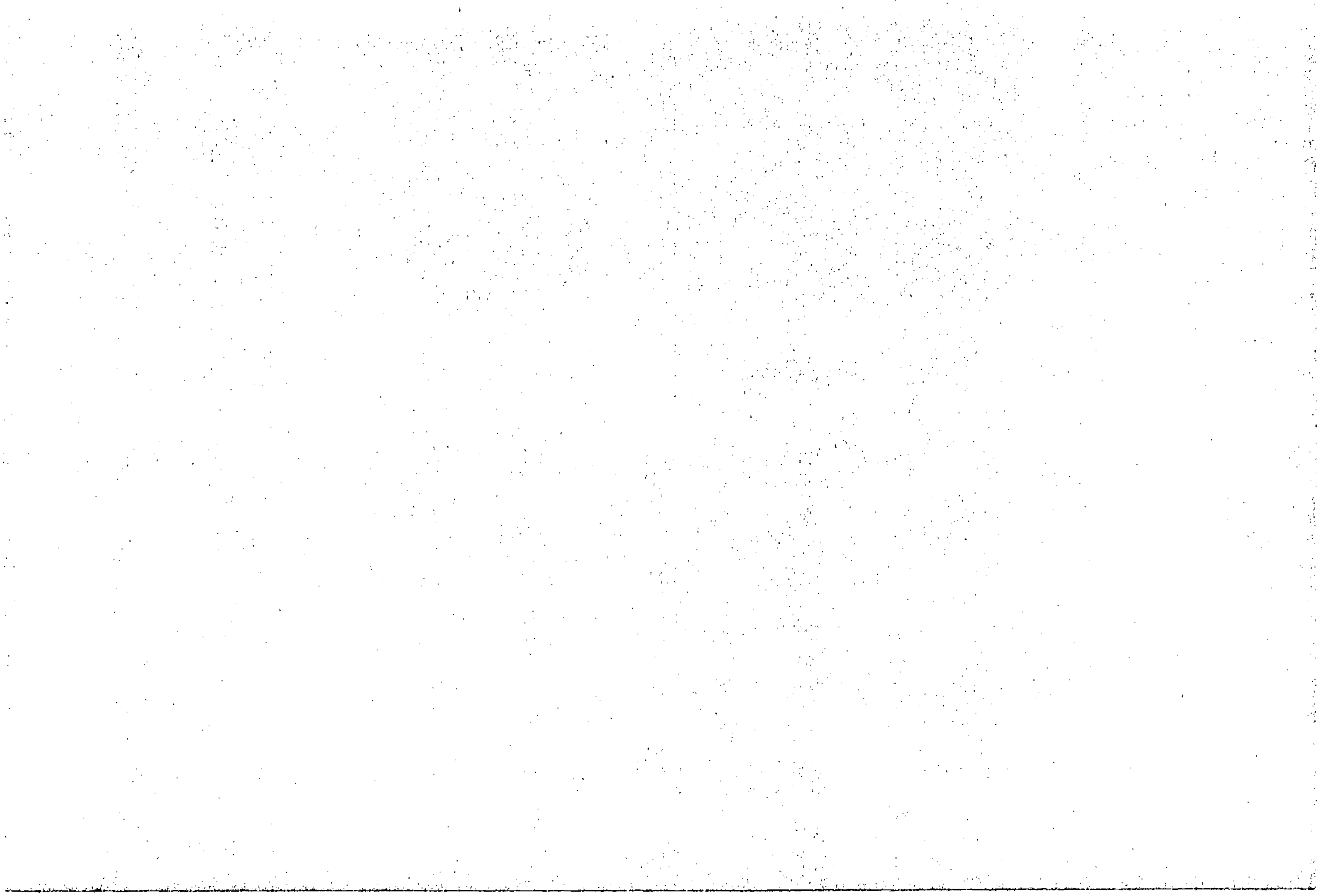


Figure VI-4. Drawing of Subcooling-Preheating Heat Exchanger HE3.

It is anticipated that the biggest thermal stresses during temperature transients will occur in the tube sheets of the two HE1 exchangers, Figure VI-2. When heat is being stored in the Research Experiment in the charging mode, steam will enter the top desuperheating exchanger at 755 K (900° F). When steam is generated by the Research Experiment discharging operation, steam will exit this exchanger at 673 K (752° F). The reversing operation requires that the steam side of the head of the heat exchanger undergo a temperature change of 83 K (150° F). Thermxchanger is collaborating with Nuclear Services of Oakland, California to determine the effect of rate of temperature change on the thermal stresses and fatigue life of the tube sheet which is 0.144 m (5-11/16 inch) thick. The study is not complete, but preliminary calculations indicate that Research Experiment operation can be reversed in 30 minutes. Details of the study will be presented in a later report.

The head of HE2, Figure VI-3, will act as the steam separator when the Thermal Storage Subsystem Research Experiment is generating steam. The water level will be maintained 0.622 m (24½ inch) above the top tube sheet during discharge. HE2 will function as a natural circulation boiler in this mode of operation, and a 0.102 m (4 inch) diameter recirculation line enters the top head 0.318 m (12½ inch) above the tube sheet. The baffle around the recirculation line entrance will minimize the amount of entrained steam vapor that is drawn down this line. The liquid level in the top head will be measured with two differential pressure sensors. The output of one sensor will be used to control and the output from the second sensor will be used to monitor the liquid level. This approach is conventional power plant practice. The bottom taps for both sensors will be located in a quiescent area inside the recirculation line baffle. A 0.152 m (6 inch) thick wire mesh drying screen is located 0.724 m (28½ inch) above the nominal liquid level. Steam will exit the top of HE2 through a 0.102 m (4 inch) diameter T-shaped dry pipe in the head. When the Research Experiment is being charged, the water level in HE2 will be maintained 0.312 m (12½ inch) above the bottom tube sheet. The liquid level will again be measured with a differential pressure sensor. The bottom tap of the sensor is located in the bottom head of HE2 and the top tap is located in the recirculation line.

HE3 is similar in construction to the HE1 units. It is the smallest of the heat exchangers and undergoes a relatively small temperature change during a reversal of operation from charging to discharging. HE3 always functions as a liquid to liquid heat exchanger and its design is the most conventional of the three units.

3. Research Experiment Tanks

Some of the design features of the salt tanks reported in the last Quarterly Report have been changed. Only one tank, the hot tank, will have three thermocouple wells. The low temperature salt tank will have two wells. The liquid level sensor for the salt tanks has been changed from a flowing nitrogen manometer to a differential pressure sensor. This level sensor will incorporate thermal isolation lines between the pressure sensing ports on the tank and the pressure cells. The isolation lines will be filled with a high temperature silicon-based oil. The liquid level will be measured in only one salt tank. The function and design of the oil tanks have not been changed.

4. Research Experiment Pumps

The pumps for the Research Experiment have been ordered. The pump specifications are given in Table VI-1. The two salt pumps which were described in the last Quarterly Report will be located in the salt tanks. Each of these pumps will pump the salt from the tank in which it is located into the other tank. The pump in T1, the hot tank, will operate only during the discharging operation, and the pump in T2, the cold tank, will operate only during the charging operation. Since these pumps will always be submerged in molten salt, there is no need to provide cooling to them when they are running, but control valve FCV1 is closed and there is no flow through the pumps. The heat generated during this operation will be carried away by the salt in the tank. The single oil pump operates during both charging and discharging. Valves are used to reverse oil flow through the heat exchangers and to the tanks. A bypass loop around this pump contains a small heat exchanger which will protect the pump from overheating during periods of low or no oil flow.

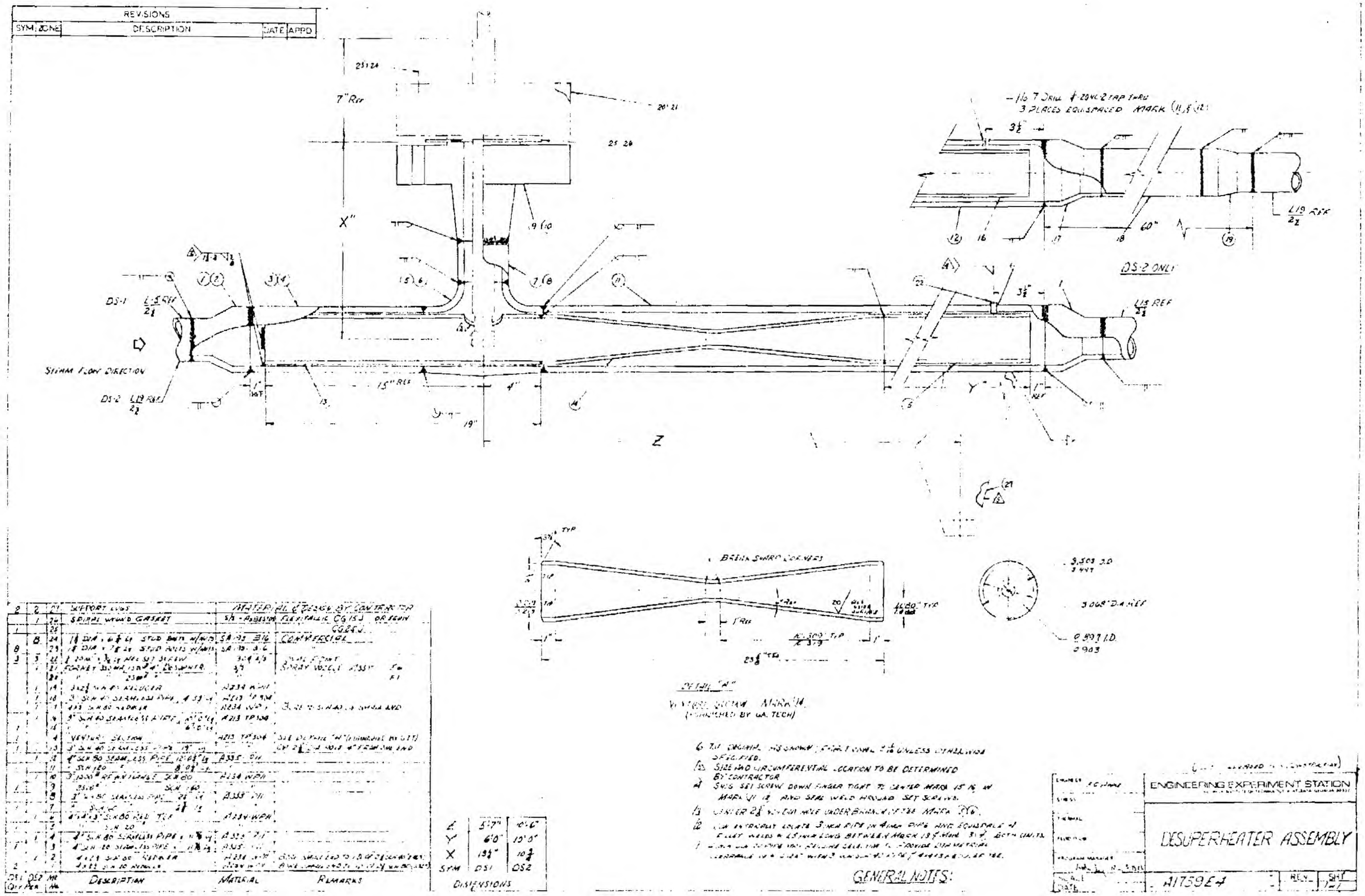
5. Desuperheater Design Considerations

The two desuperheaters, DS1 and DS2, as shown in Figure VI-5, are designed to provide full range operation from 20 to 100 percent of system flow in the charging mode under condition of operation and no-operation of heat exchanger No. 1 (HE1). The spray nozzle assemblies are commercially available Forney Engineering Co. MA-330 units. Due to the requirements for 5-to-1 turndown, venturi sections have been incorporated into the devices to provide enhanced atomization of the injected feed-water at the "low" steam flow rates. The uniqueness of these

TABLE VI-1

PUMP SPECIFICATIONS AND SUPPLIERS

Parameter	CP-1 & 2	CP-3
Storage Fluid Circulated	Heat transfer salt (molten)	Heat transfer oil (hydrocarbon oil)
Pump Type	Centrifugal, single stage	Centrifugal, single stage
Mounting	Vertical, tank mounted	Horizontal, base mounted
Casing Material	Stainless steel	Cast steel
Impeller Material	Stainless steel	Cast iron
Rated Drive Power, kW (hp)	3.73 (5)	22.37 (30)
Speed, rad/s (rpm)	183 (1750)	366 (3500)
Rated Capacity, liter/s (gpm)	1.14 (18)	25.23 (400)
Total Developed Head, m (ft)	21.34 (70)	76.20 (250)
Pump Size, Discharge x Suction mm (inch)	38.1 x 50.8 (1.5 x 2)	76.2 x 101.6 (3 x 4)
Supplier	Lawrence Pump and Engine Co. Lawrence, Massachusetts	Dean Brothers Pumps, Inc. Indianapolis, Indiana


REVISIONS
SYM. ZONE DESCRIPTION DATE APPD
7" REF
X"
Z
STEAM FLOW DIRECTION
DS-1
DS-2
15" REF
4"
19"
60"
DS-2 ONLY
BREAK SHARP CORNERS
DETAIL "A"
VENTURI SECTION MARK 14
(FURNISHED BY GA. TECH)
3.008" DIA REF
SPIRAL WOUND GASKET
VENTURI SECTION
DESCRIPTION
MATERIAL
REMARKS
Z 5'7" 10'6"
Y 6'0" 13'0"
X 13½" 10¾"
SYM DS1 DS2
DIMENSIONS
GENERAL NOTES:
ENGINEERING EXPERIMENT STATION
DESUPERHEATER ASSEMBLY
A1759E4

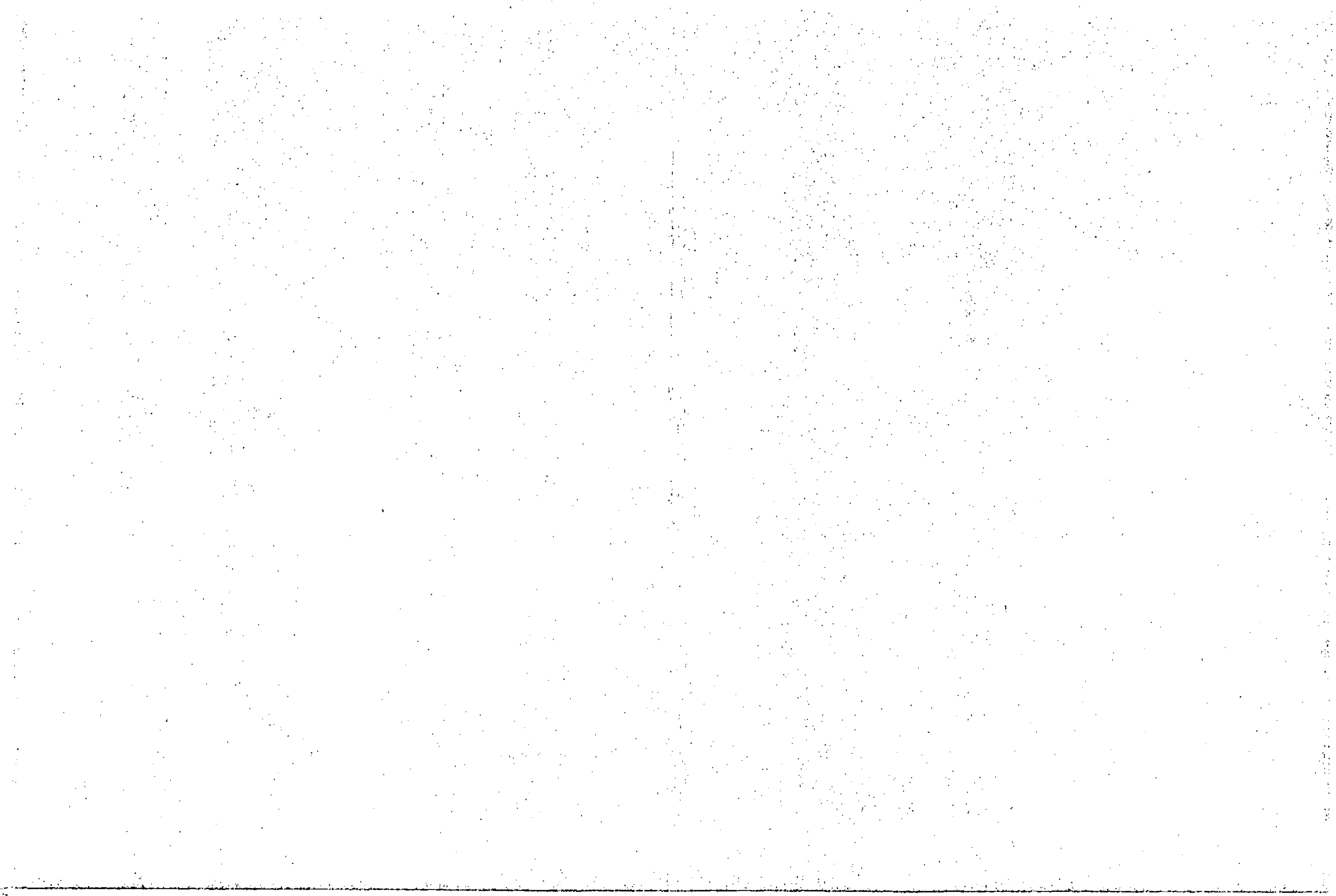


Figure VI-5. Desuperheater Drawing, Thermal Storage Subsystem Research Experiment.

venturi units is that they must function in both flow directions (i.e., charging and discharging flow) and consequently, the venturi sections are "double exit cone" designs to eliminate large pressure losses. Another feature of the desuperheaters is the incorporation of stainless steel liners which provide for resistance to thermal erosion and protect the pressure piping.

6. Piping Design Considerations

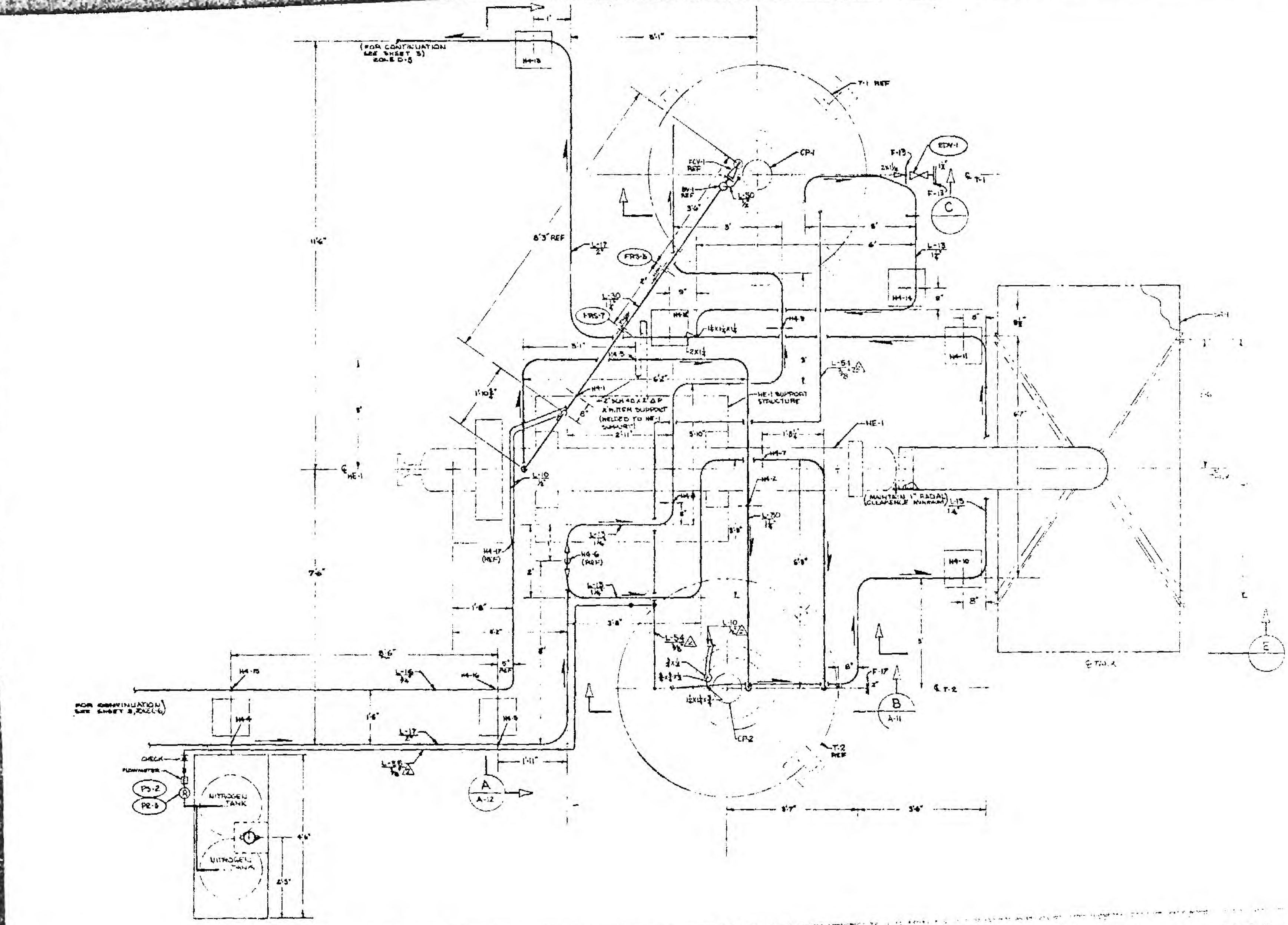
Figures VI-6 and VI-7 show two of the piping drawings for the Research Experiment. Figure VI-6 is a plan view of the salt system and VI-7 is an elevation view of the salt system. These drawings are typical of the system drawings that were included in the request for quote package that was sent to potential construction contractors. Only the molten salt and steam trace lines are shown in these figures. Both salt lines that connect the tanks to HE1 have expansion loops in them. The loop in the line connecting tank T1 to HE1 is vertical and the loop in the T2 to HE1 line is horizontal. These salt lines are traced with two 0.013 m (½ inch) diameter steam lines to preheat the lines before molten salt is pumped through them.

The salt heat exchangers are located above the storage tanks (see Figure VI-7). When the Research Experiment is not in operation, the salt lines and heat exchangers will drain back into the tanks. Most of the salt will drain into Tank T2, the low temperature tank. The salt lines slope back towards the tanks to facilitate the draining operation.

Figures VI-6 and VI-7 are two of the twelve piping installation drawings that were made during the detailed design phase of the Research Experiment. These drawings were published at the Fourth Project Review Meeting held on May 20, at the Martin Marietta Corporation in Denver, Colorado. The drawings and the design calculations including the piping code calculations constitute a major portion of the detailed design effort.

7. Research Experiment Control Console

Figure VI-8 is a drawing of the control console for the Research Experiment. The console is "layed-out" to resemble the operational schematic as much as possible. The major components are in the same relative locations and the steam and feedwater circulation lines have the same orientation. The output from all of the flow rate sensors, liquid level sensors and most of the temperature sensors can be read from meters located in the panel in their proper schematic locations.


(FOR CONTINUATION SEE SHEET 5) ZONE D-5
T-1 REF
CP-1
EDV-1
FCV-1 REF
BV-1 REF
FRS-6
FRS-7
6'3" REF
11'6"
7'6"
8'6"
HE-1 SUPPORT STRUCTURE
HE-1
MAINTAIN 1" RADIAL CLEARANCE MINIMUM
CP-2
T-2 REF
NITROGEN TANK
CHECK
FLOWMETER
PS-2
PR-3
FOR CONTINUATION SEE SHEET 3, ZONE C-6
H4-15
H4-16
H4-4
H4-5
H4-10
H4-11
H4-14

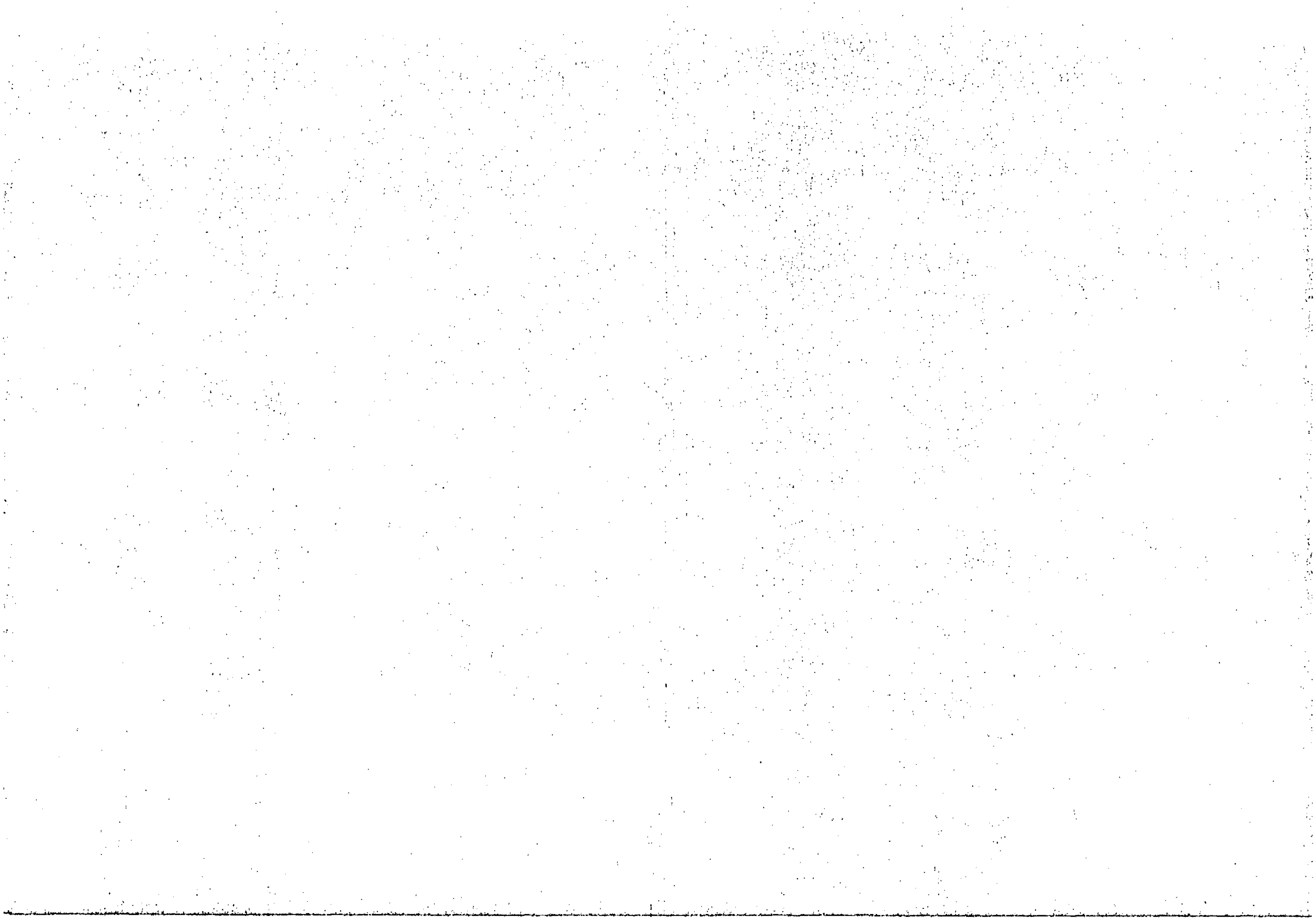
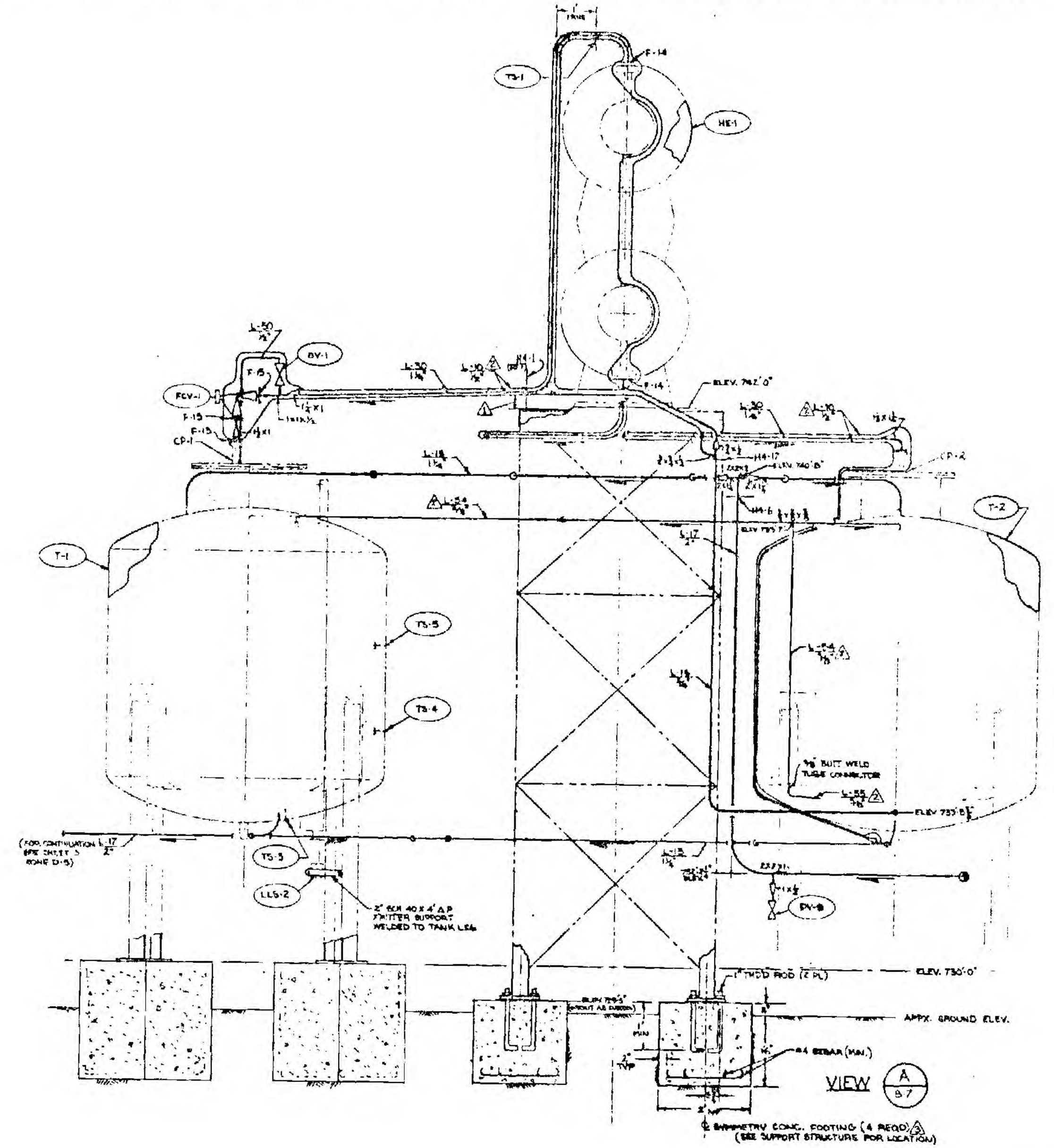


Figure VI-6. Plan View of Heat Storage Salt Piping System.



T-1
T-2
HE-1
DV-1
FCV-1
CP-1
CP-2
TS-1
TS-3
TS-4
TS-5
LLS-2
DV-8
ELEV. 762'-0"
ELEV. 730'-0"
APPX. GROUND ELEV.
#4 REBAR (MIN.)
VIEW A/9-7
℄ SYMMETRY CONC. FOOTING (4 REQD)
(SEE SUPPORT STRUCTURE FOR LOCATION)

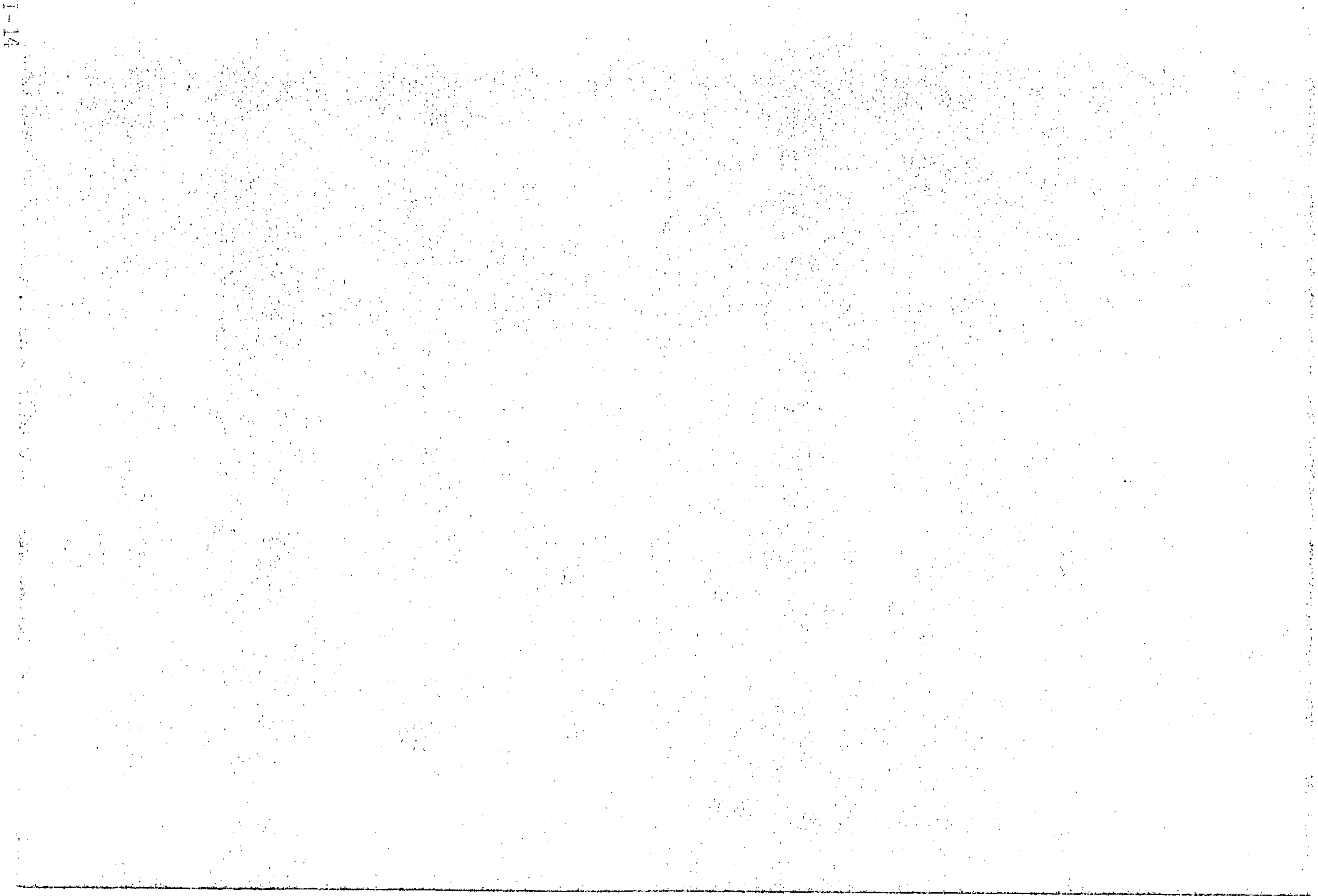
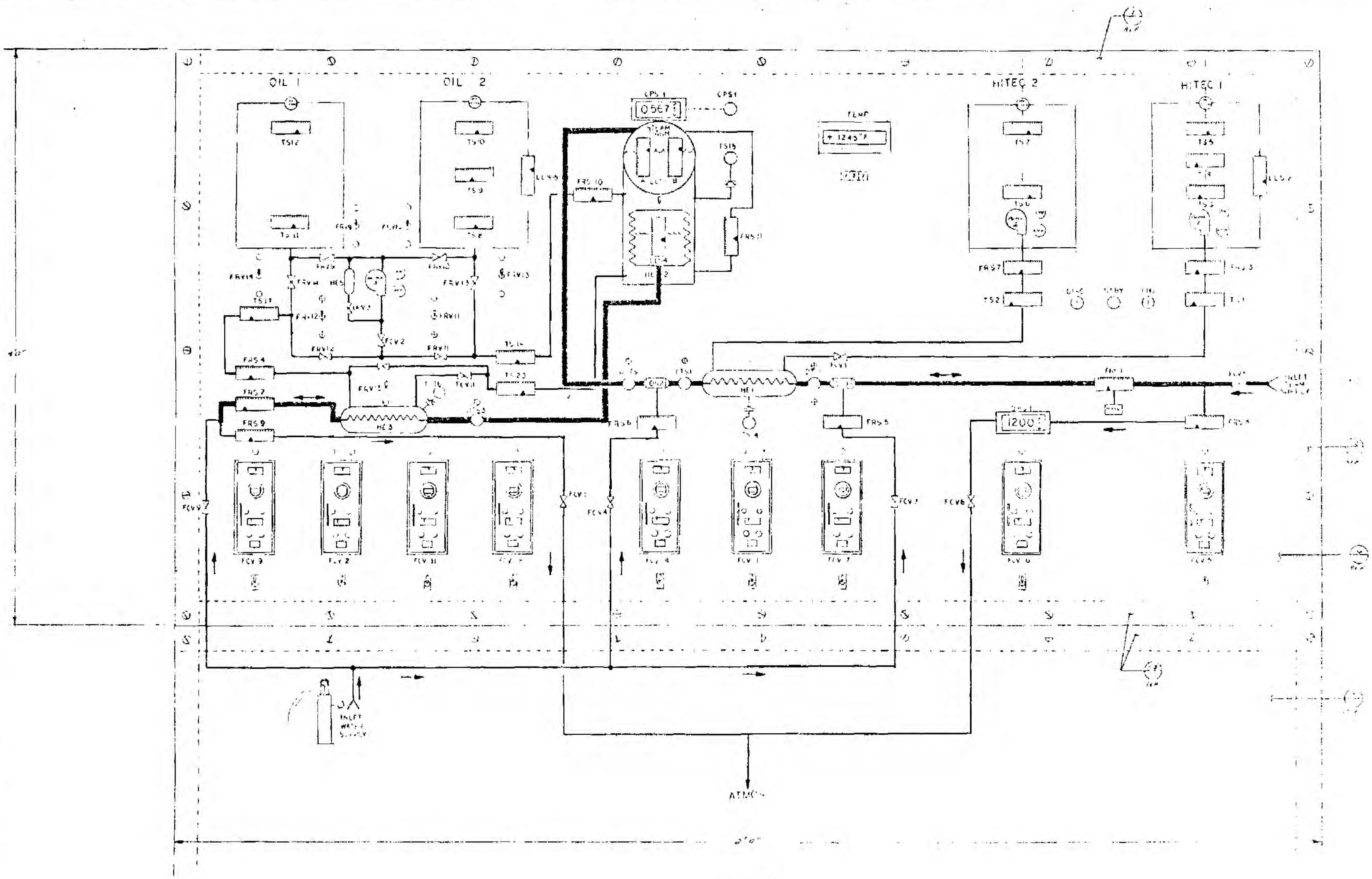


Figure VI-7. Elevation View of Heat Storage Salt Piping System.


OIL 1
OIL 2
HITEC 2
HITEC 1
CPS 1
0567
TEMP
INLET WATER SUPPLY
ATMOS
1200

1/2 SCALE

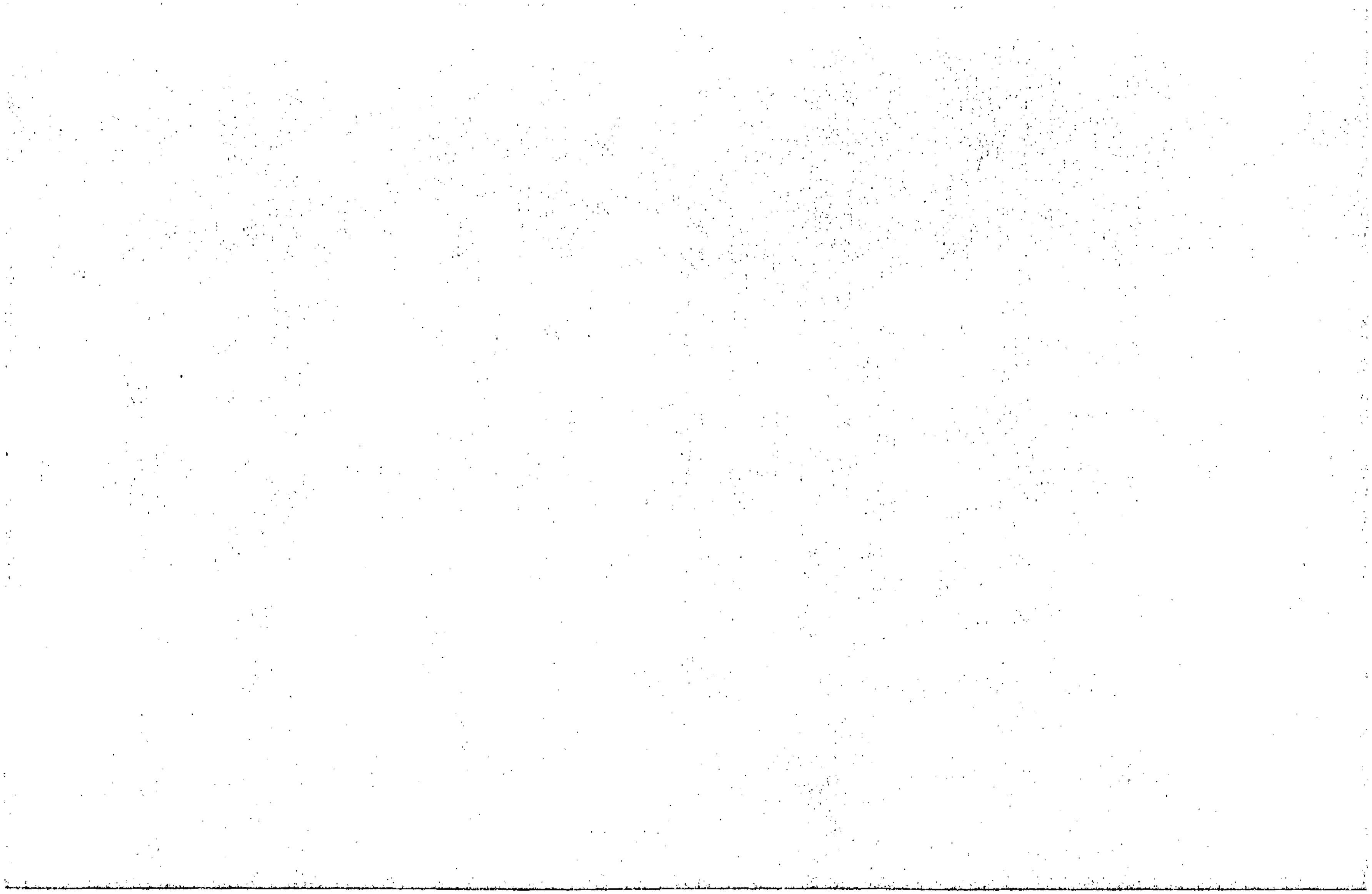


Figure VI-8. Drawing of the Research Experiment Control Panel.

Operation of the Research Experiment requires nine electronic controllers. The controllers, which are Electronic Control Systems, Inc., Model 6812 units, are located in a row across the center portion of the control panel. The nominal value of the process variable to be controlled is manually set on a digital dial on the face of the controller. Output and deviation from set point meters are located on the face of each controller. Two of these units are dual function controllers in the sense that they are used to control one process variable during charging and a different variable during discharge. The input to the FCV1 controller will come from DTS1 during discharging and from CTS1 during charging. The input for the FCV2 controller will come from DPS1 during discharging and from CPS1 during charging. When the Research Experiment is turned around from the charging mode to the discharging mode of operation, the set points of these controllers will have to be changed. The control action of both controllers will also have to be changed, for the following reason. During charging, a drop in the temperature read by CTS1 requires that FCV1 be closed as a corrective action. This action will slow the flow of salt through HE1 and raise the exit steam temperature. During discharging, a drop in the temperature read by DTS1 requires that FCV1 be opened as a corrective action. An increased flow of salt is required to raise the steam temperature. The action of the controllers is reversed by a switch located on the side of the unit. The rest of the controllers in the panel are single function units and they will not have to be adjusted during a mode reversal of the Research Experiment.

The mode selection switches for charge, discharge and standby, are located on the panel between the two salt tank lines. The standby override switch for each controller is positioned directly below the unit. This switch removes the ground from the controller output and allows actuation of the flow control valves in the standby mode. Manual switches are located next to each flow reversing valve on the control console. These switches open the corresponding valves in the standby mode.

C. TEST PLAN

The Preliminary Test Plan was outlined in the last quarterly report. During this quarter, the Final Test Plan was prepared. There are only a few significant differences between the final and preliminary test plans. An appendix was added to the Final Test Plan. The appendix included the drawings and documents referenced in the test plan. A section on operations control was added which included the control trailer arrangement, the crew organization and safety requirements. The instrumentation section was updated and the surface contact thermocouples were added to the instrumentation list. A system cleaning procedure was also added.

Detailed Test Procedures are now being written for the Research Experiment. The procedures have been grouped into nine major catagories as follows:

1. System Description - The first procedure section will contain verbal and schematic descriptions of the salt, oil and steam circuits. An instrumentation list and controls description will be included in this section.

2. Initial System Preparation - This second section will include those procedures that will only be performed once at the beginning of the test program. Some examples are the initial loading of the salt and oil and the initial component function evaluation.

3. Startup Tests - Section three will consist of the procedures that will be used to conduct the first operational tests of the Research Experiment such as the initial charging of the oil and salt systems.

4. Component Handling - Section four contains the procedures that describe the sampling and testing of water, steam, salt, etc.

5. Normal Operations - This section contains the procedures that will be used in the daily operation of the Research Experiment. Procedures for steady state and transient charging and discharging operations as well as mode reversing operations will be included.

6. Emergency Conditions - These procedures describe the steps to be taken if a major system failure such as a steam or oil line rupture occurs.

7. Disaster Plans - This section will describe the actions that should be taken to coordinate with Georgia Power Company personnel in the event of a major natural disaster.

8. Maintenance - Procedures for both preventive maintenance and component repair will be put in this section.

9. Instrumentation Calibration - The procedures here will cover the calibration of temperature, flow and level sensors as well as the readout meters, strip chart recorders and controllers.

Procedure writing began on June 4, and is scheduled to be completed before the end of August. It is intended that each procedure include every action that is required to accomplish the specified task and any cautions or unusual circumstances that operators should be aware of during execution of the procedure.

D. HYDROCARBON STORAGE FLUIDS

All hydrocarbon oils decompose. The rate of decomposition is an exponentially increasing function of increasing temperature. The products of decomposition are classifed into two groups: (1) high boilers (H.B.) those compounds that boil at temperatures higher than the fresh fluid and (2) low boiler (L.B.) those compounds that boil at temperatures lower than the fresh fluid. The H.B. concentration in a heat transfer fluid tends to increase the viscosity of the fluid. The low boilers tend to vent off and must be replaced with make up fluid.

The hydrocarbon heat transfer fluids commercially available are relatively stable, that is, they have a low decomposition rate in the temperature range of ordinary use. However, when these oils are used in a thermal storage application, large quantities of the fluid are kept at elevated temperatures for extended periods of time; under these conditions even a small decomposition rate can be important.

Three sources of decomposition data were found: Dow Chemical, Monsanto and the Atomic Energy of Canada Limited (AECL). This decomposition data is presented in Figure VI-9. This data (low cost oil line on Figure VI-9) was used to predict long term oil performance. This oil performance predication indicates that an oil maintenance unit could be necessary to continuously reprocess the oil.

There are several cautions as to how applicable the degradation data presented in the figure is to the thermal storage problem. These cautions are:

(1) The data was generated by oil and chemical companies for comparison purposes.

(2) The bulk of the data is taken at temperatures higher than the temperature range of interest of this program.

(3) Test data was generated in small sealed containers which is not like our intended use.

(4) The test samples were small which gives a large surface to volume ratio that will magnify any catalytic effect of the container as compared to our intended use.

MMC HAS ORIGINAL — SEE PAGE VI-48
OF LAST E&D A REVIEW

FIGURE VI-9 Oil Decomposition Rate as a Function of Temperature.

Figure VI-9. Oil Decomposition Rate as a Function of Temperature.

In view of the above, Sandia Labs is in the process of undertaking a test program to gather test data on oil decomposition that will be directly applicable to a thermal storage application.

Decomposition data for EXXON Caloria HT-43, Mobiltherm 500 and Therminol 55 are shown in Figure VI-9. The experiment duration is short, 8 to 10 weeks, and, it is clear from the decomposition data presented in Figure VI-9 that we will not experience any decomposition problems from any of the oils in this period of time. The Mobiltherm is currently not on the market. The Therminol 55 cost approximately $1.50 per gallon. The Caloria HT-43 cost approximately $0.85 per gallon. As such, we have selected Caloria HT-43 as the Research Experiment oil.

E. SCHEDULE

The master schedule for the Research Experiment is found in Table VI-2. All major efforts listed there are proceeding on schedule. As indicated, the activities completed during this quarter include:

(1) The detailed design of the Research Experiment.

(2) Research Experiment equipment order placement.

(3) Letting of all subcontracts, including the construction contract.

(4) Writing of the Final Test Plan.

The fabrication of major system components, heat exchangers, tanks, etc., is also proceeding on schedule. The construction of items that are critical to the program schedule is being closely monitored. An example is HE2, which must be delivered to the test site by September 3, if the construction schedule is not to be delayed. Thermxchanger, Inc., has agreed to a detailed component procurement and fabrication schedule and a report on schedule progress is being made on a regular basis.

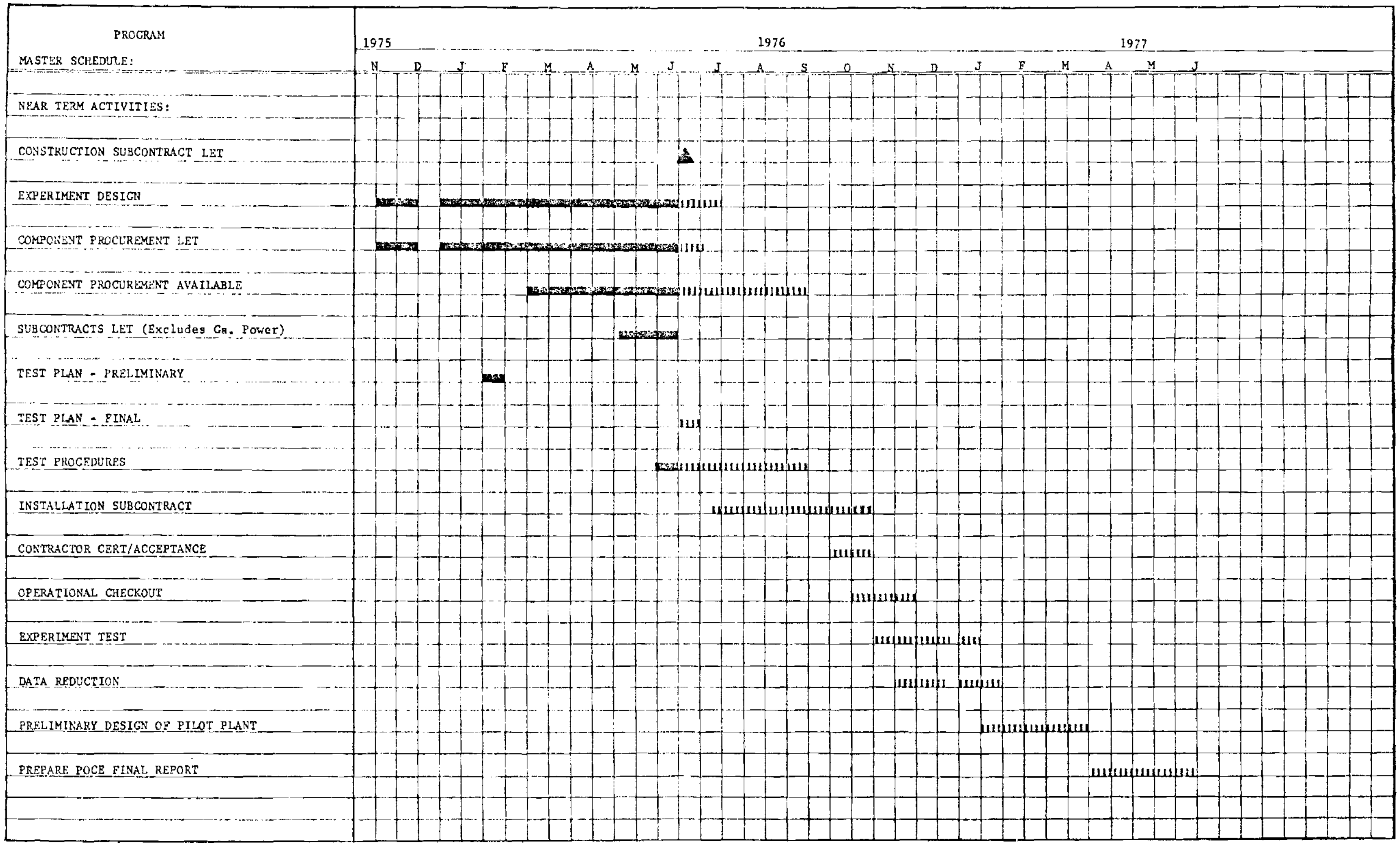
Major activities for the coming quarter will include:

(1) Monitoring of component fabrication and delivery.

(2) Generation of Research Experiment detailed procedures.

(3) The construction of the Research Experiment.

(4) Completion of the First Annual Report.



PROGRAM
MASTER SCHEDULE:
1975
1976
1977
N D J F M A M J J A S O N D J F M A M J
NEAR TERM ACTIVITIES:
CONSTRUCTION SUBCONTRACT LET
EXPERIMENT DESIGN
COMPONENT PROCUREMENT LET
COMPONENT PROCUREMENT AVAILABLE
SUBCONTRACTS LET (Excludes Ga. Power)
TEST PLAN - PRELIMINARY
TEST PLAN - FINAL
TEST PROCEDURES
INSTALLATION SUBCONTRACT
CONTRACTOR CERT/ACCEPTANCE
OPERATIONAL CHECKOUT
EXPERIMENT TEST
DATA REDUCTION
PRELIMINARY DESIGN OF PILOT PLANT
PREPARE POCE FINAL REPORT

TABLE VI-2

MASTER SCHEDULE FOR THE RESEARCH EXPERIMENT

(5) The beginning of the final pilot plant conceptual design studies.

No significant schedule changes are anticipated.

A 1759

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA GEORGIA 30332

July 13, 1976

Martin Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

Attention: Mr. John E. Myers
Mail No. S-0403

Subject: Transmittal of Georgia Tech Monthly Cost Report and Monthly Financial Report (NASA Form 533-Q) under MMC Contract RC5-230340

Gentlemen:

Attached herewith is one (1) copy of subject.

Sincerely yours,

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

jj

Enclosure: One (1) copy of Georgia Tech Monthly Cost Report and
One (1) copy of Georgia Tech Monthly Financial Report (NASA Form 533-Q)

cc: Ray Ernest, MMC (with enclosure)
Al Becker, GIT (with enclosure)
Milton Bennett, GIT (with enclosure)
File A-1759 Cost Reports

For: Ray Ernest, MMC-Denver, Ext. 2178

July 12, 1976

COST REPORT NO. 12

Georgia Tech Effort Under
M-M Contract No. RC5-230340

June 30, 1976

Prepared by

The Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

TASK	MAN-HOURS	DOLLARS ENCUMBERED	DOLLARS INCURRED
422A	201.97		2198.25
423B	144.06		1508.45
424B	194.52		2134.25
062C	179.36		1817.65
TECHNICAL REPORTS	94.59		823.20
PERSONAL SERVICES	814.50		8481.80
OVERHEAD & RETIREMENT			6823.86
MATERIALS & SUPPLIES			404.28
RESEARCH EXPERIMENT (M & S)		208253.05	927.53
RESEARCH EXPERIMENT (EQUIP)		-8003.93	11233.20
COMPUTER			626.98
TRAVEL			668.48
MONTHLY TOTALS	814.50 HRS.	$200249.12	$29166.13

For: Ray Ernest, EMC-Denver, Ext. 2178

July 12, 1976

Cumulative Totals

From June 23, 1975 - June 30, 1976

		DOLLARS	
	MAN-HOURS	ENCUMBERED	INCURRED
PERSONAL SERVICES	17847.51		169441.83
OVERHEAD & RETIREMENT			127643.68
MATERIALS & SUPPLIES			10438.44
RESEARCH EXPERIMENT (M & S)		248253.05	2145.03
RESEARCH EXPERIMENT (EQUIP)		186512.19	11233.20
COMPUTER			2672.11
TRAVEL			10752.00
TOTALS	17847.51 HRS	$434765.24	$334326.29

July 12, 1976

PURCHASE ORDER NUMBER	QTY/DESCRIPTION OF ITEM	DATE OF ENCUMBRANCE	DOLLARS ENCUMBERED	VENDOR NAME
40-Q-A1759 (EQUIP)	3 LINE FILTERS (LF3, LF4, LF5)	6/76	874.00	COWAN SUPPLY CO. (ATLANTA, GA)
46-Q-A1759 (EQUIP)	2 HOLDING TANKS (HT1, HT2)	6/76	189.16	SEARS CONTRACT SALES (ATLANTA, GA.)
45-Q-A1759 (EQUIP)	1 SIGHT GAGE & VALVES (SG1)	6/76	213.20	ROY FREEMAN ASSOC. (ATLANTA, GA.)
47-Q-A1759 (M & S)	AIR FILTER-REGULATORS AND VALVES (AFR1, AFR2, CWV1, DV6)	6/76	84.07	W. W. GRAINGER (ATLANTA, GA.)
50-Q-A1759 (M & S)	STAINLESS STEEL FOR DESUPERHEATER VENTURIS	6/76	144.59	TULL METALS (ATLANTA, GA.)
51-Q-A1759 (EQUIP)	RUPTURE DISCS AND ASSEMBLIES (PRD 3-10)	6/76	1997.70	W. R. FLACK, CO. (ATLANTA, GA.)
52-Q-A1759 (M & S)	4 VACUUM RELIEF VALVE (VRV 1-3 AND SPARE)	6/76	108.80	ROY FREEMAN ASSOC. (ATLANTA, GA.)
53-Q-A1759 (M & S)	THERMOCOUPLE ASSEMBLIES	6/76	610.00	ROY FREEMAN ASSOC. (ATLANTA, GA.)
55-Q-A1759 (M & S)	SPARE PARTS FOR SALT PUMPS	6/76	683.00	LAWRENCE PUMP (LAWRENCE, MASS)
56-Q-A1759 (M & S)	SPARE PARTS FOR OIL PUMP	6/76	469.75	DEAN BROS. (INDIANAPOLIS, IND.)
57-Q-A1759 (M & S)	NITROGEN VALVES (NV1, SV1, SV2)	6/76	666.00	YARWAY, INC. (ATLANTA, GA.)
58-Q-A1759 (M & S)	AIR COMPRESSOR BELT	6/76	39.84	W. W. GRAINGER (ATLANTA, GA.)
GTRI SUB 0003 (M & S)	CONSTRUCTION SUBCONTRACT	6/76	205647.00	BROYLES & BROYLES (ATLANTA, GA.)
54-Q-A1759 (EQUIP)	SUMP PUMP (SP1)	6/76	115.61	W. W. GRAINGER (ATLANTA, GA.)

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

August 13, 1976

Martin Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John E. Myers
Mail No. S-0403

Subject: Transmittal of Georgia Tech Monthly Cost Report and Monthly Financial Report (NASA Form 533-Q) under MMC Contract RC5-230340

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Sincerely yours,

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

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cc: Ray Ernest, MMC (with enclosure)
Al Becker, GIT (with enclosure)
Milton Bennett, GIT (with enclosure)
File A-1759 Cost Reports

For: Ray Ernest, MMC-Denver, Ext. 2178

August 12, 1976

COST REPORT NO. 13

Georgia Tech Effort Under
M-M Contract No. RC5-230340

July 31, 1976

Prepared by

The Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

TASK	MAN-HOURS	DOLLARS ENCUMBERED	DOLLARS INCURRED
442A	250.22		1,725.90
423B	418.82		3,906.76
424B	284.12		2,777.60
062A	8.66		112.99
062C	191.12		1,725.22
	1,152.94		10,248.47
PERSONAL SERVICES			
OVERHEAD & RETIREMENT			7,715.17
MATERIALS & SUPPLIES			527.19
RESEARCH EXPERIMENT (M & S)		1,571.06	333.16
RESEARCH EXPERIMENT (EQUIP)		-7,926.38	8,705.92
COMPUTER			7.37
TRAVEL			11.09
MONTHLY TOTALS	1,152.94 HRS.	$-6,355.32	$27,548.37

[illegible]

For: Ray Ernest, MMC-Denver, Ext. 2178

August 12, 1976

Cumulative Totals

From June 23, 1975 - July 31, 1976

	MAN-HOURS	DOLLARS ENCUMBERED	DOLLARS INCURRED
PERSONAL SERVICES	19,000.45		179,690.30
OVERHEAD & RETIREMENT			135,358.85
MATERIALS & SUPPLIES			10,965.63
RESEARCH EXPERIMENT (M & S)		249,824.11	2,478.19
RESEARCH EXPERIMENT (EQUIP)		178,585.81	19,939.12
COMPUTER			2,679.48
TRAVEL			10,763.09
TOTALS	19,000.45 HRS	$428,409.92	$361,874.66

For: Ray Ernest, MMC-Denver, Ext. 2178

PURCHASE ORDER NUMBER	QTY/DESCRIPTION OF ITEM	DATE OF ENCUMBRANCE	DOLLARS ENCUMBERED	VENDOR NAME
58001-Q-A1759 (M&S)	Circle Seal Valves	July	$254.30	Roy Freeman (Atlanta, GA.)
58002-Q-A1759 (M&S)	Blind Flanges	July	223.81	Consolidated Pipe (Atlanta, GA.)
58003-Q-A1759 (M&S)	Safety Hats	July	20.70	Industrial Safety
58004-Q-A1759 (M&S)	100 lbs Hitec Salt	July	42.00	Coastal Chemical (Abbeville, LA.)
58007-Q-A1759 (M&S)	Evertite Fitting	July	16.45	W. E. Marshall (Atlanta, GA.)
58008-Q-A1759 (M&S)	Spare Parts for Roy Freeman Valves	July	819.06	Roy Freeman (Atlanta, GA.)
58009-Q-A1759 (M&S)	Spare Parts for Masoneilan Valves	July	61.39	Masoneilan
58010-Q-A1759 (M&S)	Carbon Steel Plates	July	173.35	J. M. Tull (Atlanta, GA.)
58012-Q-A1759 (M&S)	Manifold Valves	July	922.00	Roy Freeman (Atlanta, GA.)
58013-Q-A1759 (M&S)	Hoke Valves	July	31.50	Activation, Inc. (Atlanta, GA.)
58014-Q-A1759 (M&S)	Robinair Valves	July	2.76	Baker Bros. (Atlanta, GA.)
58019-Q-A1759 (Equip.)	Nitrogen Valves (NV1, SV1, SV2)	July	443.88	Rockwell (Atlanta, GA.)
57-Q-A1759 (M&S)	Nitrogen Valves (NV1, SV1, SV2)		Cancelled (-666.00)	

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

September 10, 1976

Martin Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John E. Myers
Mail No. S-0403

#14

Subject: Transmittal of Georgia Tech Monthly Cost Report and Monthly Financial Report (NASA Form 533-Q) under MMC Contract RC5-230340

Gentlemen:

Attached herewith is one (1) copy of subject.

Sincerely yours,

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

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cc: Ray Ernest, MMC (with enclosure)
Al Becker, GIT (with enclosure)
Milton Bennett, GIT (with enclosure)
File A-1759 Cost Reports

For: Ray Ernest, MMC-Denver, Ext. 2178

Sept. 10, 1976

COST REPORT NO. 14

Georgia Tech Effort Under
M-M Contract No. RC5-230340

August 31, 1976

Prepared by

The Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

TASK	MAN-HOURS	DOLLARS ENCUMBERED	DOLLARS INCURRED
423B	440.48		3141.14
424B	433.26		4315.39
062C	187.76		1792.93
	1061.50		
PERSONAL SERVICES			9249.46
OVERHEAD & RETIREMENT			7144.04
MATERIALS & SUPPLIES			372.51
RESEARCH EXPERIMENT (M & S)		4445.60	1355.52
RESEARCH EXPERIMENT (EQUIP)		-3539.70	3541.18
COMPUTER			0.00
TRAVEL			36.63
MONTHLY TOTALS	1061.50 HRS.	$ 905.90	$ 21699.34

Rcd 9/10/76 J. S.

September 10, 1976

Cumulative Totals

From June 23, 1975 - August 31, 1976

	MAN-HOURS	DOLLARS ENCUMBERED	DOLLARS INCURRED
PERSONAL SERVICES	20061.95		188939.76
OVERHEAD & RETIREMENT			142502.89
MATERIALS & SUPPLIES			11338.14
RESEARCH EXPERIMENT (M & S)		254269.71	3833.71
RESEARCH EXPERIMENT (EQUIP)		175046.11	23480.30
COMPUTER			2679.48
TRAVEL			10799.72
TOTALS	20061.95 HRS	$429315.82	$383574.00

For: Ray Ernest, MMC-Denver, Ext. 2178

September 10, 1976

PURCHASE ORDER NUMBER	QTY/DESCRIPTION OF ITEM	DATE OF ENCUMBRANCE	DOLLARS ENCUMBERED	VENDOR NAME
58015-Q-A1759 (M&S)	FILTER/REGULATOR	AUGUST	$22.69	GRAINGER
58016-Q-A1759 (M&S)	2 ACTUATOR VALVES	AUGUST	44.80	CIRCLE SEAL CORP.
58017-Q-A1759 (M&S)	IMMERSON HEATERS	AUGUST	775.45	ATLAS SUPPLY
58018-Q-A1759 (M&S)	HEAT TRANSFER SALT	AUGUST	4885.84	PARK CHEMICAL COMPANY
58020-Q-A1759 (M&S)	FLEXATALLIC GASKETS	AUGUST	16.33	INDUSTRIAL PIPING SUPPLY
58022-Q-A1759 (M&S)	MISC. VALVES	AUGUST	200.60	ROY FREEMAN CO.

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

October 15, 1976

MEMORANDUM

TO: Mr. John Myers, Thermal Storage Subsystem Program Manager, Martin Marietta Corporation

FROM: Carlos Seminario

SUBJECT: Georgia Tech 533-Q for the month of September, 1976, MMC Contract RC5-230340

Subject report is based on Georgia Tech budget dated 4/12/76, contract value is $1025935. Although this dollar amount was changed in the Review Meeting held at Georgia Tech on 9/20/76, official MMC revised contract value has not been received here to date.

Please send Contract Amendment revising total contract value as soon as possible.

Thank you.

Carlos Seminario
Program Operations Coordinator
Solar Energy & Materials
Technology Division

jj

cc: Ray Ernest, MMC
Al Becker, GIT
Milton Bennett, GIT
File A-1759 Cost Reports

F-1-1

For: Ray Ernest, MMC-Denver, Ext. 2178

October 12, 1976

COST REPORT NO. 15

Georgia Tech Effort Under
M-M Contract No. RC5-230340

September 30, 1976

Prepared by

The Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

TASK	MAN-HOURS	DOLLARS ENCUMBERED	DOLLARS INCURRED
423B	250.09		2237.17
424B	322.12		3117.40
062A	65.66		781.55
062C	287.95		2895.42
TECHNICAL REPORTS	11.46		100.58
	937.28		
PERSONAL SERVICES			9132.12
OVERHEAD & RETIREMENT			6987.67
MATERIALS & SUPPLIES			81.61
RESEARCH EXPERIMENT (M & S)		-64343.36	67009.38
RESEARCH EXPERIMENT (EQUIP)		-54094.76	53500.45
COMPUTER			0.00
TRAVEL			750.76
MONTHLY TOTALS	937.28 HRS.	$ -118438.12	$ 137,461.99

For: Ray Ernest, MMC-Denver, Ext. 2178

October 12, 1976

Cumulative Totals

From June 23, 1975 - September 30, 1976

		DOLLARS	
	MAN-HOURS	ENCUMBERED	INCURRED
PERSONAL SERVICES	20999.23		198071.88
OVERHEAD & RETIREMENT			149490.56
MATERIALS & SUPPLIES			11419.75
RESEARCH EXPERIMENT (M & S)		189926.35	70843.09
RESEARCH EXPERIMENT (EQUIP)		120951.35	76980.75
COMPUTER			2679.48
TRAVEL			11550.48
TOTALS	20999.23 HRS	$310877.70	$ 521035.99

For: Ray Ernest, MMC-Denver, Ext. 2178

October 12, 1976

PURCHASE ORDER NUMBER	QTY/DESCRIPTION OF ITEM	DATE OF ENCUMBRANCE	DOLLARS ENCUMBERED	VENDOR NAME
58023-Q-A1759 (M&S)	RESEARCH EXPERIMENT CLEANING SERVICES	SEPTEMBER	1852.00	HALLIBURTON SERVICES
58025-Q-A1759 (M&S)	SALT TANK FILL CHUTE	SEPTEMBER	85.00	ADVANCED METAL
58026-Q-A1759 (M&S)	BLIND FLANGE	SEPTEMBER	68.46	HUB, INC.
58027-Q-A1759 (M&S)	B-16 BOLTS	SEPTEMBER	76.00	SOUTHEASTERN BOLT & SCREW
58028-Q-A1759 (M&S)	PACKING SETS FOR YARWAY VALVES	SEPTEMBER	116.78	YARWAY CORP.
58029-Q-A1759 (M&S)	CIRCLE SEAL VALVES	SEPTEMBER	195.45	ROY FREEMAN, ASSOCIATES
58030-Q-A1759 (M&S)	TUBING FITTINGS	SEPTEMBER	121.09	ORTON, CO.

FOR MR. RAY ERNEST EXT. 2178

A-1759
revised #15

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

November 3, 1976

TO: Mr. Ray Ernest, Contract Administrator, MMC-Denver

FROM: Carlos Seminario, SEMTD

SUBJECT: Amendment to Georgia Tech September 1976 Cost Report and 533-Q Management Report under MMC Contract No. RC5-230340

REFERENCE: Georgia Tech Research Institute Invoice to Martin Marietta Corp. dated October 13, 1976 for the period 9/1/76-9/30/76

During September 1976, the Georgia Tech Research Institute paid Thermxchanger, Inc. the amount of $115,306 for three Heat Exchangers to be utilized during the conduct of the Research Experiment under subject contract. This expenditure, however, was not incurred in the subject cost reports at the time of their issue. Nevertheless, Martin Marietta was invoiced for those Heat Exchangers in the referenced invoice. Therefore, subject reports have been adjusted in order to reflect the payment to Thermxchanger, Inc., and reconciliation with referenced invoice.

Attachment I amends the September cost report total expenditures for the month from $137,461.99 to $252,767.99. The "Research Experiment (Equip)" encumbrances changed from $-54,094.76 to $-169,283.76 and expenditures from $53,500.45 to $168,806.45. Attachment II amends the September 533-Q to the expenditures in the "Research Experiment" category from $120,510 to $235,806.

Please accept my apologies for this inconvenience.

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

Attachments

jw

cc: Mr. John Myers, MMC-D
Mr. Milton Bennett, GIT
Mr. Al Becker, GIT ✓

I

For: Ray Ernest, MMC-Denver, Ext. 2178

October 12, 1976

COST REPORT NO. 15

Georgia Tech Effort Under
M-M Contract No. RC5-230340

September 30, 1976

Prepared by

The Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

TASK	MAN-HOURS	DOLLARS ENCUMBERED	DOLLARS INCURRED
423B	250.09		2237.17
424B	322.12		3117.40
062A	65.66		781.55
062C	287.95		2895.42
TECHNICAL REPORTS	11.46		100.58
	937.28		
PERSONAL SERVICES			9132.12
OVERHEAD & RETIREMENT			6987.67
MATERIALS & SUPPLIES			81.61
RESEARCH EXPERIMENT (M & S)		-64343.36	67009.38
RESEARCH EXPERIMENT (EQUIP)		-169283.76	168806.45
COMPUTER			0.00
TRAVEL			750.76
MONTHLY TOTALS	937.28 HRS.	$ -233627.12	$252767.99

October 12, 1976

Cumulative Totals

From June 23, 1975 - September 30, 1976

		DOLLARS	
	MAN-HOURS	ENCUMBERED	INCURRED
PERSONAL SERVICES	20999.23		198071.88
OVERHEAD & RETIREMENT			149490.56
MATERIALS & SUPPLIES			11419.75
RESEARCH EXPERIMENT (M & S)		189926.35	70843.09
RESEARCH EXPERIMENT (EQUIP)		5762.24	192286.75
COMPUTER			2679.48
TRAVEL			11550.48
TOTALS	20999.23 HRS	$195688.70	$636341.99

For: Ray Ernest, MMC-Denver, Ext. 2178

October 12, 1976

PURCHASE ORDER NUMBER	QTY/DESCRIPTION OF ITEM	DATE OF ENCUMBRANCE	DOLLARS ENCUMBERED	VENDOR NAME
58023-Q-A1759 (M&S)	RESEARCH EXPERIMENT CLEANING SERVICES	SEPTEMBER	1852.00	HALLIBURTON SERVICES
58025-Q-A1759 (M&S)	SALT TANK FILL CHUTE	SEPTEMBER	85.00	ADVANCED METAL
58026-Q-A1759 (M&S)	BLIND FLANGE	SEPTEMBER	68.46	HUB, INC.
58027-Q-A1759 (M&S)	B-16 BOLTS	SEPTEMBER	76.00	SOUTHEASTERN BOLT & SCREW
58028-Q-A1759 (M&S)	PACKING SETS FOR YARWAY VALVES	SEPTEMBER	116.78	YARWAY CORP.
58029-Q-A1759 (M&S)	CIRCLE SEAL VALVES	SEPTEMBER	195.45	ROY FREEMAN, ASSOCIATES
58030-Q-A1759 (M&S)	TUBING FITTINGS	SEPTEMBER	121.09	ORTON, CO.

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

November 15, 1976

Martin Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John E. Myers
Mail No. S-0403

No. 16

Subject: Transmittal of Georgia Tech Monthly Cost Report and Monthly Financial Report (NASA Form 533-Q) under MMC Contract RC5-230340

Gentlemen:

Attached herewith is one (1) copy of subject.

Sincerely yours,

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

cp

Enclosure: One (1) copy of Georgia Tech Monthly Cost Report and One (1) copy of Georgia Tech Monthly Financial Report (NASA Form 533-Q)

cc: Ray Ernest, MMC (with enclosure)
Al Becker, GIT (with enclosure)
Milton Bennett, GIT (with enclosure)
File A-1759 Cost Reports

For: Ray Ernest, MMC-Denver, Ext. 2178

November 12, 1976

COST REPORT NO. 16

Georgia Tech Effort Under
M-M Contract No. RC5-230340

October 31, 1976

Prepared by

The Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

TASK	MAN-HOURS	DOLLARS ENCUMBERED	DOLLARS INCURRED
423B	510.43		5151.81
424B	131.16		1332.56
062C	227.84		2023.62
Technical Reports	168.71		1825.46
PERSONAL SERVICES	1038.14		10333.45
OVERHEAD & RETIREMENT			7798.75
MATERIALS & SUPPLIES			373.81
RESEARCH EXPERIMENT (M & S)		14909.73	2840.20
RESEARCH EXPERIMENT (EQUIP)		- 4726.70	4775.69
COMPUTER			0.00
TRAVEL			91.84
MONTHLY TOTALS	1038.14 HRS.	$ 10183.03	$ 26213.74

For: Ray Ernest, MMC-Denver, Ext. 2178

November 12, 1976

Cumulative Totals

From June 23, 1975 - October 31, 1976

	MAN-HOURS	DOLLARS ENCUMBERED	DOLLARS INCURRED
PERSONAL SERVICES	22037.37		208405.33
OVERHEAD & RETIREMENT			157289.31
MATERIALS & SUPPLIES			11793.56
RESEARCH EXPERIMENT (M & S)		204836.08	73683.29
RESEARCH EXPERIMENT (EQUIP)		1035.54	197062.44
COMPUTER			2679.48
TRAVEL			11642.32
TOTALS	22037.37HRS	$205871.62	$662555.73

For: Ray Ernest, MMC-Denver, Ext. 2178

November 12, 1976

PURCHASE ORDER NUMBER	QTY/DESCRIPTION OF ITEM	DATE OF ENCUMBRANCE	DOLLARS ENCUMBERED	VENDOR NAME
21-Q-A-1759 (M&S)	EXXON CALORIA HT43 18150 GALLONS	OCTOBER	15518.25	EXXON CO.
32-Q-A-1759 (M&S)	SS TUBING	OCTOBER	125.44	J. M. TULL
35-Q-A-1759 36-Q-A-1759 (M&S)	TOOLS	OCTOBER	167.95	ZIEGLER
37-Q-A-1759 (M&S)	EXTENSION CORDS	OCTOBER	75.67	W. W. GRAINGER
40-Q-A-1759 (M&S)	FIRE EXTINGUISHER	OCTOBER	326.40	DIXIE FIRE EXTINGUISHER
41-Q-A-1759 42-Q-A-1759 43-Q-A-1759 (M&S)	LIQUID NITROGEN TANKS	OCTOBER	400.00	PYE BARKER WELDING

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

December 15, 1976

Martin Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John E. Myers
Mail No. S-0403

Subject: Transmittal of Georgia Tech Monthly Cost Report and Monthly Financial Report (NASA Form 533 Q) under MMC Contract RC5-230340

Gentlemen:

Attached herewith is one (1) copy of subject.

Sincerely yours,

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

gp

Enclosure: One (1) copy of Georgia Tech Monthly Cost Report and
One (1) copy of Georgia Tech Monthly Financial Report (NASA Form 533-Q)

cc: Ray Ernest, MMC (with enclosure)
Al Becker, GIT (with enclosure)
Milton Bennett. GIT (with enclosure)
File A-1759 Cost Reports

For: Ray Ernest, MMC-Denver, Ext. 2178

December 13, 1976

COST REPORT NO. 17

Georgia Tech Effort Under
M-M Contract No. RC5-230340

November 30, 1976

Prepared by

The Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

TASK	MAN-HOURS	DOLLARS ENCUMBERED	DOLLARS INCURRED
412	96.66	-	1052.12
423 B	826.29	-	8393.27
062 C	222.90	-	1901.21
PERSONAL SERVICES	1145.85	-	11346.60
OVERHEAD & RETIREMENT	-	-	8572.09
MATERIALS & SUPPLIES	-	-	79.80
RESEARCH EXPERIMENT (M & S)	-	-87929.31	92571.01
RESEARCH EXPERIMENT (EQUIP)	-	-1035.54	929.00
COMPUTER	-	-	2.42
TRAVEL	-	-	703.03
MONTHLY TOTALS	1145.85 HRS.	$-88964.85	$114203.95

For: Ray Ernest, MMC-Denver, Ext. 2178

December 13, 1976

Cumulative Totals

From June 23, 1975 = November 30, 1976

		DOLLARS	
	MAN-HOURS	ENCUMBERED	INCURRED
PERSONAL SERVICES	23183.22	-	219751.93
OVERHEAD & RETIREMENT	-	-	165861.40
MATERIALS & SUPPLIES	-	-	11873.36
RESEARCH EXPERIMENT (M & S)	-	116906.77	166254.30
RESEARCH EXPERIMENT (EQUIP)	-	-	197991.44
COMPUTER	-	-	2681.90
TRAVEL	-	-	12345.35
TOTALS	23183.22 HRS	$ 116906.77	$ 776759.68

For: Ray Ernest, MMC-Denver, Ext. 2178

December 13, 1976

PURCHASE ORDER NUMBER	QTY/DESCRIPTION OF ITEM	DATE OF ENCUMBRANCE	DOLLARS ENCUMBERED	VENDOR NAME
44-Q-A-1759 (M & S)	WATER CHEMISTRY SUPPLIES	NOVEMBER	720.56	FISHER SCIENTIFIC
46-Q-A-1759 (M & S)	WATER CHEMISTRY SUPPLIES	NOVEMBER	142.92	FISHER SCIENTIFIC
47-Q-A-1759 (M & S)	WATER CHEMISTRY SUPPLIES	NOVEMBER	46.04	FISHER SCIENTIFIC

A-1759

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

December 28, 1976

MEMORANDUM

TO: Mr. Ray Ernest, Contract Administrator, MMC - Denver

FROM: Carlos Seminario, SEMTD

SUBJECT: Georgia Tech Monthly Financial Report (NASA Form 533Q) under MMC Contract RC5-230340

The subject report included herewith shows an underspending of $89,385.00. Once again, Research Experiment expenditures are not taking place according to the April, 1976 spend plan as can be evidenced by the $83,407.00 underspending in this category. The 533Q data base is still the April 12, 1976 budget.

It should be pointed out at this time that Georgia Tech is projecting a program overrun of approximately $48,000.00, of which approximately $20,000.00 is due to changes in Research Experiment components and subcontract codes and 28,000.00 is due to an unforeseen expense of having to install additional feedwater and steam lines to an alternate steam generating unit at Georgia Power Company Plant Yates. As you know, Georgia Power Company is subcontracted by Georgia Tech to supply steam and feedwater to the thermal storage research experiment. An overrun proposal explaining in detail these cost overruns is forthcoming from the Georgia Tech Office of Contract Administration.

It is expected that by the next issue date of the 533Q, Georgia Tech will be working with a revised budget data base.

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

gp

cc: John E. Myers, MMC
Al Becker, GIT
Milton Bennett, GIT
File A-1759 Cost Reports

A-1151

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

January 15, 1977

Martin-Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John E. Myers
Mail No. S-0403

#18

Subject: Transmittal of Georgia Tech Monthly Cost Report and Monthly Financial Report (NASA Form 533 Q) under MMC Contract RC5-230340

Gentlemen:

Attached herewith is one (1) copy of subject.

Sincerely,

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

dr

Enclosure: One (1) copy of Georgia Tech Monthly Cost Report and
One (1) copy of Georgia Tech Monthly Financial Report (NASA Form 533-Q)

cc: Ray Ernest, MMC (with enclosure)
Al Becker, GIT (with enclosure)
Milton Bennett, GIT (with enclosure)
File A-1759 Cost Reports

For: Ray Ernest, MMC-Denver, Ext. 2178

January 12, 1977

COST REPORT NO. 18

Georgia Tech Effort Under
M-M Contract No. RC5-230340

December 31, 1976

Prepared by

The Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

TASK	MAN-HOURS	DOLLARS ENCUMBERED	DOLLARS INCURRED
412	34.34		364.17
423B	758.94		7,775.02
042C	19.70		272.85
062A	28.32		406.07
062C	236.05		2,051.29
Economic Analysis	46.08		560.00
PERSONAL SERVICES	1,123.43		11,429.40
OVERHEAD & RETIREMENT			8,619.37
MATERIALS & SUPPLIES			698.32
RESEARCH EXPERIMENT (M & S)		13,719.68	38,403.25
RESEARCH EXPERIMENT (EQUIP)			0.00
COMPUTER			0.00
TRAVEL			1,295.66
MONTHLY TOTALS	1,123.43 HRS.	$ 13,719.68	$ 60,446.00

Cumulative Totals

From June 23, 1975 - December 31, 1976

		DOLLARS	
	MAN-HOURS	ENCUMBERED	INCURRED
PERSONAL SERVICES	24,306.65		231,181.33
OVERHEAD & RETIREMENT			174,480.77
MATERIALS & SUPPLIES		130,626.45	12,571.68
RESEARCH EXPERIMENT (M & S)			204,657.55
RESEARCH EXPERIMENT (EQUIP)			197,991.44
COMPUTER			2,681.90
TRAVEL			13,641.01
TOTALS	24,306.65 HRS	$130,626.45	$837,205.68

For: Ray Ernest, MMC-Denver, Ext. 2178

January 12, 1977

PURCHASE ORDER NUMBER	QTY/DESCRIPTION OF ITEM	DATE OF ENCUMBRANCE	DOLLARS ENCUMBERED	VENDOR NAME
58049-Q-A1759 (M & S)	Spare Parts for Valtek Valves	DECEMBER	225.30	Roy Freeman
58050-Q-A1759 (M & S)	Beckman Instrument Supplies	DECEMBER	62.00	Beckman
58052-Q-A1759 (M & S)	Vacuum Supports for Rupture Discs	DECEMBER	273.12	Fike Metal Products
2-Q-A1759-001 (M & S)	Georgia Power Co. (New Work)	DECEMBER	31,824.00	Georgia Power
2-Q-A1759-001 (M & S)	Georgia Power Co. (Increases to Budget)	DECEMBER	6,878.00	Georgia Power
3-Q-A1759-001 (M & S)	Broyles & Broyles (Increases to Budget)	DECEMBER	9,947.00	Broyles & Broyles

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

February 11, 1977

Martin-Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John E. Myers
Mail No. S-0403

#19

Subject: Transmittal of Georgia Tech Monthly Cost Report and Monthly Financial Report (NASA Form 533 Q) under MMC Contract RC5-230340

Gentlemen:

Attached herewith is one (1) copy of subject.

Sincerely,

Carlos Seminario
Program Operations Coordinator
Solar Energy & Materials
Technology Division

dr

Enclosure: One (1) copy of Georgia Tech Monthly Cost Report and One (1) copy of Georgia Tech Monthly Financial Report (NASA Form 533-Q)

cc: Ray Ernest, MMC (with enclosure)
Al Becker, GIT (with enclosure)
Milton Bennett, GIT (with enclosure)
File A-1759 Cost Reports

For: Ray Ernest, MMC-Denver, Ext. 2178

February 11, 1977

COST REPORT NO. 19

Georgia Tech Effort Under
M-M Contract No. RC5-230340

January 31, 1977

Prepared by

The Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

TASK	MAN-HOURS	DOLLARS ENCUMBERED	DOLLARS INCURRED
410	199.18		1,990.99
424B	1,049.12		7,974.83
062C	232.01		2,053.24
Technical Reports	67.30		639.36
Economic Analysis	146.16		1,785.56
PERSONAL SERVICES	1,693.77		14,443.98
OVERHEAD & RETIREMENT			10,698.29
MATERIALS & SUPPLIES			80.15
RESEARCH EXPERIMENT (M & S)		-6,583.74	10,594.61
RESEARCH EXPERIMENT (EQUIP)			97.99
COMPUTER			0.00
TRAVEL			1,416.72
MONTHLY TOTALS	1,693.77 HRS.	-$6,583.74	$37,331.74

For: Ray Ernest, MMC-Denver, Ext. 2178

February 11, 1977

Cumulative Totals

From June 23, 1975 - January 31, 1977

	MAN-HOURS	DOLLARS ENCUMBERED	DOLLARS INCURRED
PERSONAL SERVICES	26,000.42		245,625.31
OVERHEAD & RETIREMENT			185,179.06
MATERIALS & SUPPLIES			12,651.83
RESEARCH EXPERIMENT (M & S)		124,042.71	215,252.16
RESEARCH EXPERIMENT (EQUIP)			198,089.43
COMPUTER			2,681.90
TRAVEL			15,057.73
TOTALS	26,000.42 HRS	$ 124,042.71	$ 874,537.42

For: Ray Ernest, MMC-Denver, Ext. 2178

February 11, 1977

PURCHASE ORDER NUMBER	QTY/DESCRIPTION OF ITEM	DATE OF ENCUMBRANCE	DOLLARS ENCUMBERED	VENDOR NAME
58044-Q-A1759 (M & S)	Water Chemistry Supplies (Adjustment)	January	17.33	Fisher
58055-Q-A1759 (M & S)	Portable John	January	102.00	Cobb Porta-John
58056-Q-A1759 (M & S)	Water Chemistry Supplies	January	21.59	Fisher
58057-Q-A1759 (M & S)	Valve Positioner	January	169.00	Roy Freeman
58058-Q-A1759 (M & S)	I/P Converter	January	228.00	Masoneilan
58059-Q-A1759 (M & S)	Dessicators	January	342.00	King Engineer
58060-Q-A1759 (M & S)	Heat Tape	January	302.10	Applebee-Church
58061-Q-A1759 (M & S)	Liquid Nitrogen	January	500.00	Pye Barker Welding

A-1759

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

March 15, 1977

Martin Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John E. Myers
Mail No. S-0403

Subject: Transmittal of Georgia Tech Monthly Cost Report and Monthly Financial Report (NASA Form 533-Q) under MMC Contract RC5-230340

Gentlemen:

Attached herewith is one (1) copy of subject.

Sincerely yours,

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

dr

Enclosure: One (1) copy of Georgia Tech Monthly Cost Report and
One (1) copy of Georgia Tech Monthly Financial Report (NASA Form 533-Q)

cc: Ray Ernest, MMC (with enclosure)
Al Becker, GIT (with enclosure)
Milton Bennett, GIT (with enclosure)
File A-1759 Cost Reports

For: Ray Ernest, MMC-Denver, Ext. 2178

March 14, 1977

COST REPORT NO. 20

Georgia Tech Effort Under
M-M Contract No. RC5-230340

February 28, 1977

Prepared by

The Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

TASK	MAN-HOURS	DOLLARS ENCUMBERED	DOLLARS INCURRED
410	677.55		6,469.94
424B	692.75		5,335.25
062C	186.26		1,606.63
Economic Analysis	229.09		2,568.42
PERSONAL SERVICES	1,785.65		15,980.24
OVERHEAD & RETIREMENT			11,904.34
MATERIALS & SUPPLIES			273.40
RESEARCH EXPERIMENT (M & S)		-47,634.79	49,590.88
RESEARCH EXPERIMENT (EQUIP)			0.00
COMPUTER			0.00
TRAVEL			527.16
MONTHLY TOTALS	1,785.65 HRS.	-$47,634.79	$ 78,276.02

March 14, 1977

Cumulative Totals

From June 23, 1975 - February 28, 1977

	MAN-HOURS	DOLLARS ENCUMBERED	DOLLARS INCURRED
PERSONAL SERVICES	27,786.07		261,605.55
OVERHEAD & RETIREMENT			197,083.40
MATERIALS & SUPPLIES			12,925.23
RESEARCH EXPERIMENT (M & S)		76,407.92	264,843.04
RESEARCH EXPERIMENT (EQUIP)			198,089.43
COMPUTER			2,681.90
TRAVEL			15,584.89
TOTALS	27,786.07 HRS	$76,407.92	$952,813.44

For: Ray Ernest, MMC-Denver, Ext. 2178

March 14, 1977

PURCHASE ORDER NUMBER	QTY/DESCRIPTION OF ITEM	DATE OF ENCUMBRANCE	DOLLARS ENCUMBERED	VENDOR NAME
66-Q-A-1759 (M & S)	Silica Gel	February	$26.58	Fisher
67-Q-A-1759 (M & S)	Scaffolding Rental	February	189.00	Upright Scaffolds

A-1759 I

ENGINEERING EXPERIMENT STATION

GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

April 15, 1977

Martin-Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John E. Myers
Mail No. S-0403

Subject: Transmittal of Georgia Tech Monthly Cost Report #21 and Monthly Financial Report #21 (NASA Form 533-Q) under MMC Contract RC5-230340

Gentlemen:

Attached herewith is one (1) copy of subject.

Sincerely yours,

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

dr

Enclosure: One (1) copy of Georgia Tech Monthly Cost Report and
One (1) copy of Georgia Tech Monthly Financial Report (NASA Form 533-Q)

cc: Ray Ernest, MMC (with enclosure)
Al Becker, GIT (with enclosure)
Milton Bennett, GIT (with enclosure)
File A-1759 Costs Reports

For: Ray Ernest, MMC-Denver, Ext. 2178

April 12, 1977

COST REPORT NO. 21

Georgia Tech Effort Under
M-M Contract No. RC5-230340

March 31, 1977

Prepared by

The Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

		DOLLARS	
TASK	MAN-HOURS	ENCUMBERED	INCURRED
410	926.64		8,391.54
424B	324.12		1,909.91
062C	107.58		1,174.97
Technical Reports	112.98		977.51
Economic Analysis	336.43		3,825.68
PERSONAL SERVICES	1,807.75		16,279.61
OVERHEAD & RETIREMENT			12,282.24
MATERIALS & SUPPLIES			323.80
RESEARCH EXPERIMENT (M & S)		-32,349.69	33,111.59
RESEARCH EXPERIMENT (EQUIP)			0.00
COMPUTER			6.96
TRAVEL			1,249.09
MONTHLY TOTALS	1,807.75 HRS.	$ -32,349.69	$63,253.29

For: Ray Ernest, MMC-Denver, Ext. 2178

April 12, 1977

Cumulative Totals

From June 23, 1975 - March 31, 1977

	MAN-HOURS	DOLLARS ENCUMBERED	DOLLARS INCURRED
PERSONAL SERVICES	29,593.82		277,885.16
OVERHEAD & RETIREMENT			209,365.64
MATERIALS & SUPPLIES			13,249.03
RESEARCH EXPERIMENT (M & S)		44,058.23	297,954.63
RESEARCH EXPERIMENT (EQUIP)			198,089.43
COMPUTER			2,688.86
TRAVEL			16,833.98
TOTALS	29,593.82 HRS	$ 44,058.23	$ 1,016,066.73

For: Ray Ernest, MMC-Denver, Ext. 2178

April 12, 1977

PURCHASE ORDER NUMBER	QTY/DESCRIPTION OF ITEM	DATE OF ENCUMBRANCE	DOLLARS ENCUMBERED	VENDOR NAME
58068-Q-A1759 (M & S)	Liquid Nitrogen	March	500.00	Pye Barker Welding

A-1759
received 2 cys
26 May 77

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

May 17, 1977

Martin-Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John E. Myers
Mail No. S-0403

Subject: Transmittal of Georgia Tech Monthly Cost Report and Monthly Financial Report (NASA Form 533-Q) under MMC Contract RC5-230340

Gentlemen:

Attached herewith is one (1) copy of subject.

Sincerely,

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

dr

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File A-1759 Cost Reports

NOTE: CUMULATIVE PROGRAM EXPENDITURES SHOWN IN THE ENCLOSED COST REPORTS DO NOT REFLECT TOTAL PROGRAM COST. PROGRAM EXPENDITURES OUTSTANDING WILL BE INCLUDED IN THE JUNE, 1977 GEORGIA TECH INVOICE.

For: Ray Ernest, MMC-Denver, Ext. 2178

May 17, 1977

COST REPORT NO. 22

Georgia Tech Effort Under
M-M Contract No. RC5-230340

April 30, 1977

Prepared by

The Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

TASK	MAN-HOURS	DOLLARS ENCUMBERED	DOLLARS INCURRED
410	202.17		829.00
062A	162.40		1,346.50
062C	155.66		1,810.46
Economic Analysis	578.83		6,162.85
PERSONAL SERVICES	1,099.06		10,148.81
OVERHEAD & RETIREMENT			7,950.61
MATERIALS & SUPPLIES			663.38
RESEARCH EXPERIMENT (M & S)		-32,569.95	32,626.31
RESEARCH EXPERIMENT (EQUIP)			0.00
COMPUTER			7.74
TRAVEL			1,335.44
MONTHLY TOTALS	1,099.06 HRS.	$ -32,569.95	$ 52,732.29

For: Ray Ernest, MMC-Denver, Ext. 2178

May 17, 1977

Cumulative Totals

From June 23, 1975 - April 30, 1977

	MAN-HOURS	DOLLARS: ENCUMBERED	DOLLARS: INCURRED
PERSONAL SERVICES	30,692.88		288,033.97
OVERHEAD & RETIREMENT			217,316.25
MATERIALS & SUPPLIES			13,912.41
RESEARCH EXPERIMENT (M & S)		11,488.28	330,580.94
RESEARCH EXPERIMENT (EQUIP)			198,089.43
COMPUTER			2,696.60
TRAVEL			18,169.42
TOTALS	30,692.88 HRS	$ 11,488.28	$ 1,068,799.02

For: Ray Ernest, MMC-Denver, Ext. 2178

May 17, 1977

PURCHASE ORDER NUMBER	QTY/DESCRIPTION OF ITEM	DATE OF ENCUMBRANCE	DOLLARS ENCUMBERED	VENDOR NAME
NONE				

A-1759

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

June 15, 1977

received 2 cys
8 Jul 77

Martin-Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

ATTENTION: Mr. John E. Myers
Mail No. S-0403

Subject: Transmittal of Georgia Tech Monthly Cost Report under MMC Contract RC5-230340

Gentlemen:

Attached herewith is one (1) copy of subject.

Sincerely,

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

dr

Enclosure: One (1) copy of Georgia Tech Monthly Cost Report

cc: Ray Ernest, MMC (with enclosure)
Al Becker, GIT (with enclosure)
Milton Bennett, GIT (with enclosure)
File A-1759 Cost Reports

NOTE: CUMULATIVE PROGRAM EXPENDITURES SHOWN IN THE ENCLOSED COST REPORT DOES NOT REFLECT TOTAL PROGRAM COST.

For: Ray Ernest, MMC-Denver, Ext. 2178

June 13, 1977

COST REPORT NO. 23

Georgia Tech Effort Under
M-M Contract No. RC5-230340

May 31, 1977

Prepared by

The Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

TASK	MAN-HOURS	DOLLARS ENCUMBERED	DOLLARS INCURRED
410	22.5		85.03
062C	77.0		533.26
Economic Analysis	7.0		94.93
Res. Exp. Data Summary	24.0		252.79
HE1 Rework Costing	14.0		189.86
PERSONAL SERVICES	144.5		1,155.87
OVERHEAD & RETIREMENT			1,522.47
MATERIALS & SUPPLIES			386.03
RESEARCH EXPERIMENT (M & S)		-11,488.28	3,833.27
RESEARCH EXPERIMENT (EQUIP)			0.00
COMPUTER			4.57
TRAVEL			-51.53
MONTHLY TOTALS	144.5 HRS.	-$ 11,488.28	$ 6,850.68

June 13, 1977

Cumulative Totals

From June 23, 1975 - May 31, 1977

	MAN-HOURS	DOLLARS ENCUMBERED	DOLLARS INCURRED
PERSONAL SERVICES	30,837.38		289,189.84
OVERHEAD & RETIREMENT			218,838.72
MATERIALS & SUPPLIES			14,298.44
RESEARCH EXPERIMENT (M & S)			334,414.21
RESEARCH EXPERIMENT (EQUIP)			198,089.43
COMPUTER			2,701.17
TRAVEL			18,117.89
TOTALS	30,837.38 HRS	$	$ 1,075,649.70

*CUMULATIVE CHARGES OF $1,075,649.70 DOES NOT REFLECT TOTAL PROGRAM COST.

For: Ray Ernest, MMC-Denver, Ext. 2178

June 13, 1977

PURCHASE ORDER NUMBER	QTY/DESCRIPTION OF ITEM	DATE OF ENCUMBRANCE	DOLLARS ENCUMBERED	VENDOR NAME
NONE				

A-1759

CENTRAL RECEIVER SOLAR THERMAL POWER SYSTEM (PHASE 1)

Annual Progress Report Number 1

SECTION IV

THERMAL STORAGE SUBSYSTEM

Authors:

Steve H. Bomar, Jr.

Ralph F. Altman

Charles A. Murphy

John E. Myers (MMC)

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Engineering Experiment Station
Georgia Institute of Technology

A. INTRODUCTION

The Martin Marietta Central Receiver Solar Thermal Power System team is structured so that program responsibilities are divided among the members of the team, under the overall direction of the Martin Marietta Corporation. The Thermal Storage Subsystem is the responsibility of the Engineering Experiment Station of the Georgia Institute of Technology. The major activities in this area of the program include development of a preliminary design for a 10 MWe Pilot Plant Thermal Storage Subsystem and the design, construction and testing of a Thermal Storage Subsystem Research Experiment; various other tasks such as cost estimating and engineering support are also underway.

1. Program Objectives

The objective of the program presently under contract is to complete a preliminary design of a solar thermal electric power generation system which will have the ability to feed electricity into a commercial power distribution grid. If this design, or parts thereof, are selected for further development, subsequent contracts would cover detailed design and construction of the 10 MWe Pilot Plant and a test program to permit acquisition of operating experience and demonstration of feasibility.

In its request for proposal, ERDA specified that the Pilot Plant preliminary design would incorporate thermal storage and that its capacity would be sized to maintain the electrical output of the plant at 70 percent of its nominal value for six hours. In its proposal to ERDA, the Martin Marietta team selected a storage system design concept based on storage of sensible heat in liquid media. The reasons for this choice were: (1) storage in liquid media has a high probability of technical success because much of the necessary technology exists, and (2) the possibility of program delays caused by technical difficulties would be reduced by selecting this approach because thermal storage was the least well-defined of the plant subsystems and unexpected delays in this area could impact the schedule of the entire program.

The Thermal Storage Subsystem is an integral part of the solar thermal Pilot Plant. It must supply steam to the turbine in the Electrical Power Generation Subsystem at temperatures and pressures acceptable to the turbine and it must accept steam from the Receiver Subsystem at the receiver's output conditions. Its controls must be integrated with the remainder of the plant and it must serve as a buffering device to smooth steam flow rates in some operating modes.

The specific objectives of the Georgia Tech portion of the Martin Marietta Pilot Plant program are: (1) to analyze the requirements of the Pilot Plant Thermal Storage Subsystem and develop a preliminary design, (2) to develop a conceptual design of the Thermal Storage Subsystem Research Experiment based on the Pilot Plant preliminary design, (3) to develop a detailed design for the Thermal Storage

Subsystem Research Experiment, (4) to build and test the Thermal Storage Subsystem Research Experiment, and (5) to revise the preliminary design of the Pilot Plant Thermal Storage Subsystem using the results of the Research Experiment activity. Other subsidiary objectives such as program management, participation in coordination and design review activities, preparation of technical reports, etc. are included within the technical objectives.

2. Summary of Progress Through Reporting Date

This report describes the technical progress during the first 15 months of the program. Details of the program accomplishments are described in the following sections of the report, but a broad summary is appropriate at this point to illustrate major milestones:

a. Pilot Plant Preliminary Design

- Subsystem analyses have been conducted to define Thermal Storage Subsystem requirements and assure compatibility with other subsystems.
- Alternate thermal storage approaches have been evaluated to determine whether a change in concept should be recommended.
- An analytical performance model based on the Martin Interactive Thermal Analysis System (MITAS) heat transfer computer program has been developed.
- Heat exchangers, piping, tanks and other process equipment have been sized and preliminary detailed schematics and ground layout drawings have been prepared.
- Users of candidate storage fluids have been visited, a heat transfer salt has been selected as the higher temperature fluid and a hydrocarbon oil has been selected as the lower temperature fluid.
- Subsystem specifications have been updated and preliminary reliability allocations established.
- A Preliminary Design Baseline Review has been conducted and ERDA approval received.
- A preliminary cost estimate for the 10 MWe Pilot Plant has been prepared and submitted.

b. Thermal Storage Subsystem Research Experiment

- A Research Experiment has been defined based on the Pilot Plant preliminary design baseline; the charging and discharging rates are 2 MWth and the storage capacity is 1.6 MW-hr.

- Arrangements have been made for construction of the Research Experiment at Plant Yates of the Georgia Power Company, near Newnan, Georgia; the Georgia Power Company will supply superheated steam and feedwater for test operations.

- An analytical performance model based on the MITAS computer program has been developed for the Research Experiment.

- Conceptual and detailed designs for the Research Experiment have been completed; Design Reviews have been conducted and ERDA approval received.

- Subcontracts and Purchase Orders have been issued for equipment and components of the Research Experiment; all materials have arrived except the storage media which are scheduled for delivery.

- Subcontracts have been issued for construction and cleaning; construction is in progress.

- A Test Plan for the Research Experiment has been prepared and approved.

- Operating Procedures for the Research Experiment have been prepared; approvals and changes are in progress.

c. Other Program Activities

- A short series of elevated temperature aging tests on candidate oils was conducted.

- An investigation of the stability of oil storage media has been conducted.

B. PILOT PLANT THERMAL STORAGE SUBSYSTEM

The preliminary baseline design of the Pilot Plant Thermal Storage Subsystem has been completed. As part of this effort, the storage concept was reviewed and finalized, major components were identified and sized and a ground layout of the system was completed. In addition, two basic operating modes were defined: charging of energy into the storage system and discharging of energy from the storage system.

In the charging mode, superheated steam from the solar central receiver will be passed through a heat exchanger where it will be cooled to a temperature near its saturation temperature. Simultaneously, a molten eutectic salt mixture, heat transfer salt (HTS), will be circulated through the heat exchanger countercurrently to the steam. This process raises the temperature of the heat transfer salt to approximately 728 K (850° F) and it is stored at that temperature for subsequent use during discharging. The steam continues to another heat exchanger where it is condensed to remove its latent heat. In this heat exchanger a hydrocarbon oil circulates countercurrently to the steam and is thereby heated to approximately 567 K (560° F); the oil storage medium is also stored for subsequent use during discharging. Finally, the liquid water resulting from condensation of the steam passes to a third heat exchanger where additional heat is removed and stored in oil. During discharging of the storage system, all fluid flow directions are reversed and liquid water is converted to superheated steam. This approach to thermal energy storage results in a highly reliable system capable of meeting all of the requirements for Pilot Plant Thermal Storage.

1. <u>Requirements for Pilot Plant Thermal Storage Subsystem</u>

The Thermal Storage Subsystem has three basic requirements:

- To store the thermal energy in any portion of the output from the Receiver Subsystem, from full steam flow to very low flow.
- To provide steam to the Electrical Power Generation Subsystem (EPGS) for generation of at least 7 MWe net for a continuous period of up to 6 hours or lower rates for correspondingly longer times.
- To provide steam with acceptable conditions for maintaining operation of the turbine during cloud transients and for protection of plant equipment during shutdown periods.

In order to satisfy the first requirement, the Thermal Storage Subsystem was designed to extract heat from steam at flow rates up to 61,236 kg/h (135,000 lb/h). Steam will enter the Storage Subsystem at 8825 kPa (1280 psig) and 784 K (950° F). To meet the second requirement, 4137 kPa (600 psig), 700 K (800° F) steam can be discharged from storage at a maximum rate of 57,380 kg/h (126,000 lb/h). The minimum design flow rate is 2268 kg/h (5000 lb/h) for both the charging and the discharging operations. The storage subsystem also contains equipment to generate sealing steam for the turbine and condenser in the EPGS when the turbine is operating in the standby mode. The sealing steam, which satisfies the second part of the third requirement above, will be delivered at 1034 kPa (150 psig), 459 K (366° F) at a rate of 454 kg/h (1000 lb/h). These flow rates and steam states are summarized in Table VI-1.

TABLE VI-1

PILOT PLANT THERMAL STORAGE STEAM FLOWS AND STATE POINTS

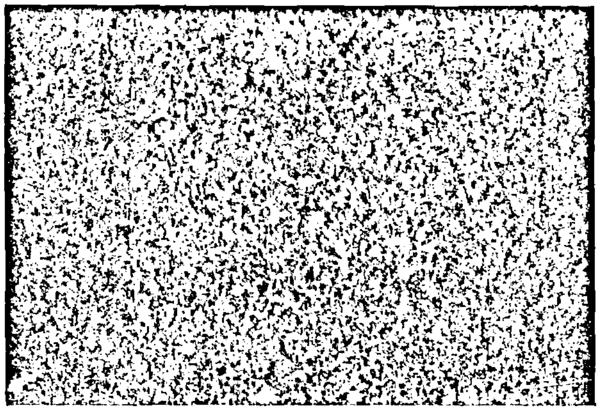
Parameter	Charging	Discharging
Inlet or Outlet Temperature	784 K (950^{o} F)	700 K (800^{o} F)
Inlet or Outlet Pressure	8,825 kPa (1250 psig)	4137 kPa (600 psig)
Max Flow Rate	61,236 kg/h (135,000 lb/h)	57,380 kg/h (126,000 lb/h)
Min Flow Rate	2268 kg/h (5000 lb/h)	2268 kg/h (5000 lb/h)

2. Thermal Storage Feasibility Studies

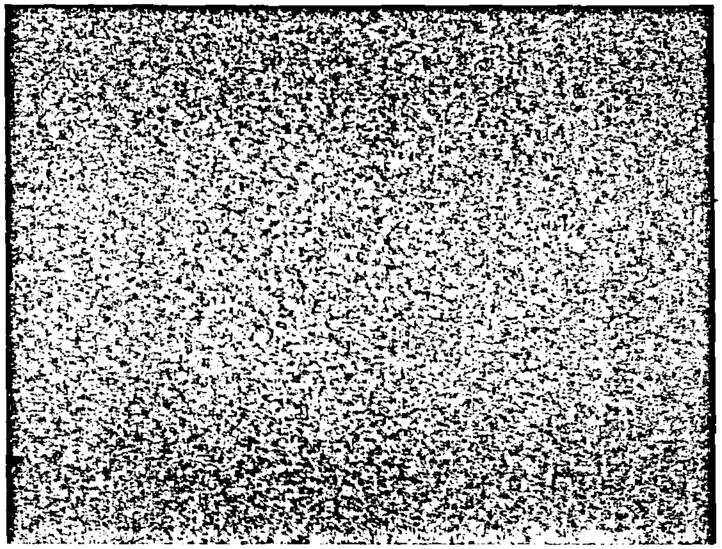
During the early stages of the Thermal Storage design, three approaches to thermal storage were considered. The details of this concept study were published in the First Quarterly Report for the Central Receiver Solar Thermal Power System, Phase One Program; a description of the concepts and summary of the conclusions drawn from the study will be presented here.

Three storage concepts are illustrated in Figure VI-1. In the simplest concept heat would be stored as sensible heat in a pumped liquid storage medium. The principle of operation of a liquid sensible heat system is depicted in the top diagram of Figure VI-1. When heat is being stored in the system (charging operation), liquid is pumped from a low temperature reservoir through a heat exchanger. The storage medium is heated in the heat exchanger by cooling or condensing steam or liquid condensate and flows into a high temperature reservoir. At some later time, heat can be extracted from the hot liquid (discharging operation) by passing it back through the same or a different heat exchanger where it heats or evaporates water or steam. The storage medium then flows back into the low temperature reservoir. This process of heating and cooling a liquid in a heat exchanger is a common industrial practice. All of the fluids that were considered for use in the Thermal Storage Subsystem have a long record of industrial usage in heat exchange application. Building a liquid sensible heat storage device is largely a matter of adapting existing technology to a new usage.

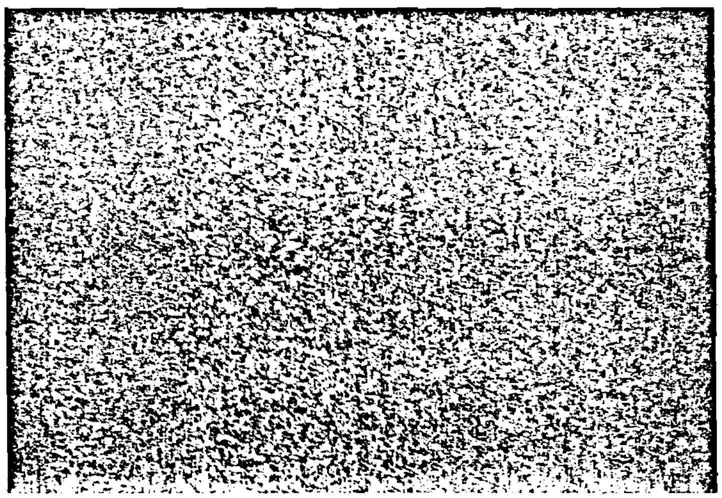
In the second approach studied, heat would be stored as sensible heat in a solid storage medium. The storage medium would be an inexpensive



Sensible Heat Fluid Storage System



Sensible Heat Solid Storage System



Encapsulated Salt Latent Heat Storage System

Figure VI-1. Thermal Storage System Concepts.

material, either rocks or scrap metal. The principle of operation of the solid sensible heat storage concept is independent of the storage medium and this principle is illustrated in the middle diagram of Figure VI-1. The solid storage medium, in this case rocks, is contained in a tank. A heat transport fluid, such as a hydrocarbon oil, is circulated in a loop through the tank and through a heat exchanger. When heat is being charged into the medium, the heat transport fluid will absorb heat in the heat exchanger and then flow into the top of the storage tank. As the fluid flows down through the tank, it gives up heat to the colder rocks. The fluid does not just flow through the tank one time. It is continuously circulated through the tank and back through the heat exchanger. As the charging process continues, a thermal gradient is established along the length of the tank. If charging continues long enough, the rocks at the top of the tank reach a temperature very close to the temperature of the incoming oil, and the oil leaving the bottom of the tank has a temperature close to the temperature of the cold rocks at the bottom of the bed.

In a well designed storage system of this kind, the thermal gradient will be relatively sharp and most of the solid medium will undergo a large temperature change as the gradient travels down the length of the tank. The volumetric efficiency for a sharp thermal gradient is high. If the thermal gradient is long compared to the length of the tank, a portion of the solid medium will undergo only a small temperature change, and the volumetric efficiency will be low. The size of the tanks and amount of storage medium increases under these conditions, and as a consequence the cost of the storage system goes up. The character of the thermal gradient depends on the thermal parameters of the heat transfer fluid and the solid medium, as well as the size, shape and packing of the solid medium. MITAS, the thermal analysis program described elsewhere in this report, has been used to model a stone bed. The results indicate that an economical stone storage system can be built if relatively small stones are used.

To extract heat from a solid-filled heat storage tank, the flow of the heat transfer fluid is reversed. The cold fluid flows in the bottom of the tank, is heated as it passes up through the solid storage medium and then flows back through the heat exchanger where it gives up heat. During this process, the movement of the thermal gradient is also reversed. The gradient now moves from the bottom of the tank towards the top.

A latent heat thermal storage system was the third concept investigated at the beginning of the program. The system would use an inorganic salt encapsulated in thin wall tubes. These tubes would be placed in a tank in bundles. A heat transfer fluid would circulate through the tank to either melt the salt in the tubes by giving up heat to it or solidify the salt by absorbing heat from it. The dead space in the tubes would be filled with an inert gas such as nitrogen or helium to enhance heat conduction from the tube wall to the solid mass at the beginning of the melting process. The molten salt concept is diagrammed in the bottom illustration of Figure VI-1.

The operation of the system is similar in many ways to the operation of the solid sensible heat system just described. When heat is being stored in the system, hot oil would flow into the top of the tank and down through the tube bundle giving up heat to the salt in the tubes. The thin tube wall would have little thermal resistance, and the tube diameter would be small so that the heat conduction path into the salt would be short. These two design considerations would allow high charge and discharge rates to be maintained throughout the entire melting and solidification processes. A thermal gradient and melting gradient would form in the tank and move down the axis of the tank as charging continued. During discharge, the oil flow through the tank would be reversed. The direction of the thermal/melting gradient would also reverse. Again, the thermal and melting gradients should be sharp to minimize the size of the storage system.

At the end of the storage concept study, it was concluded that a storage system based on any of the three concepts was feasible. The last two systems, the solid sensible heat and molten salt systems, were potentially the cheapest systems to build. However, reliability is of prime importance in the role that thermal storage is to play in the solar powered electric generating plant, and it was also concluded that the development effort required to produce a highly reliable storage system based on either of these concepts was inappropriate for this program. Table VI-2 contains a summary of problems that would have to be understood before a reliable plant with a thirty-year lifetime could be proposed with confidence. Some of the problems listed in Table VI-2 would require long-term studies in order to document reliability and lifetime of the proposed solutions.

On the other hand, a Thermal Storage System based on the liquid sensible heat principle that is reliable and has a predictable lifetime requires only a modest development effort. Low cost heat transfer liquids with a long record of industrial usage in heat exchange applications are readily available. Building a liquid sensible heat storage device is largely a matter of adapting existing technology to a new usage. For these reasons, the Baseline Design incorporates a Thermal Storage Subsystem based on the liquid sensible heat approach.

3. Pilot Plant Thermal Storage Subsystem Baseline Design

A conceptual schematic for the Pilot Plant Thermal Storage Subsystem Baseline Design is shown in Figure VI-2. The design is based on a two-stage liquid sensible heat concept. The high temperature stage employs a molten salt for the storage medium. A hydrocarbon oil is used as the storage medium in the low temperature stage.

TABLE VI-2

PROBLEM AREAS IN SOLID SENSIBLE HEAT AND MOLTEN SALT THERMAL STORAGE SYSTEMS

(1) The solid sensible heat system requires that oil be pumped through the tank. The tanks are large and must operate at low pressure to minimize their cost. This system therefore requires that the oil be pumped into and out of the tank with sufficient controls to ensure that the tanks are not overpressurized.

(2) The solid media will have a tendency to settle in the tanks. The settling will produce an effective pressure on the tank walls and the thickness of the tank side must be increased in order to accommodate this effective pressure.

(3) If rocks are used, they will be a self-generating contamination source. Filters and settling tanks may be required to protect heat exchanger and flow control equipment.

(4) The long term chemical compatibility of oil and rocks at high temperature is unknown, and the chemical composition of the rocks will vary depending on the source of the stone.

(5) Flow may tend to channelize in both the solid sensible heat and the molten salt systems. If channelization occurs, baffles that will increase the cost of the system will be required.

(6) In order to achieve a steep thermal gradient in the tank, fluid velocities will probably have to be high and the pumping costs will be high.

(7) The long-term chemical stability of salts at high temperatures is not well known. As most salts degrade, they tend to evolve gas which can cause pressure build up in the tubes. A salt composition change may shift the melting point or degrade the heat of fusion.

(8) The long term compatibility of the salt and the tube metal at high temperatures must be understood.

(9) As the salt thaws and freezes its volume will change putting some stress on the tubes. The tubes must be designed to stand this cyclic stress.

(10) A manufacturing process would need to be developed to encapsulate the large volume salt into tubes economically.

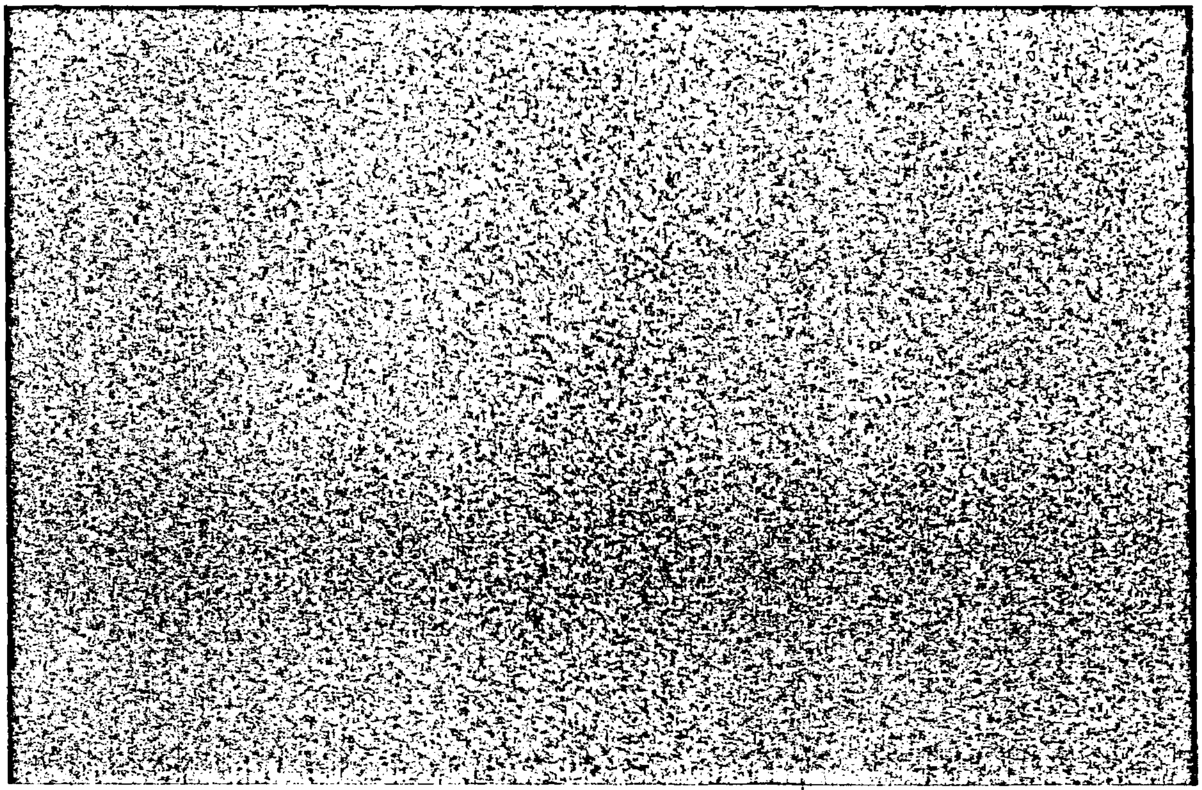


Figure VI-2. Two-Stage Thermal Storage Subsystem Conceptual Schematic.

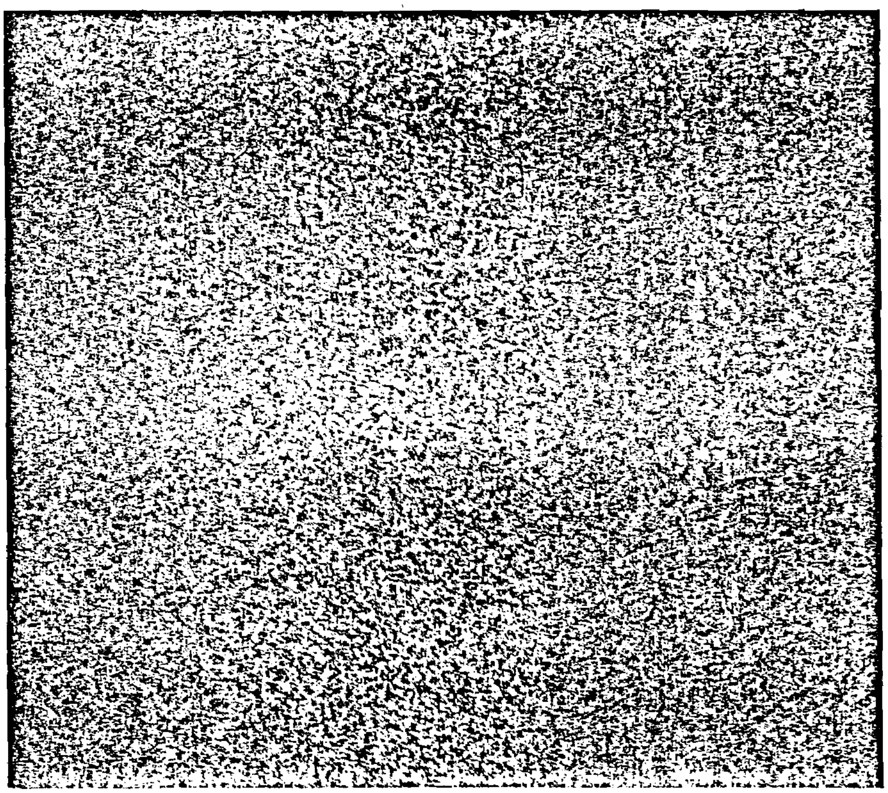


Figure VI-3. Heat Balance for Two-Stage Thermal Storage Subsystem.

During charging, the system operates as follows: Superheated steam at 784 K (950° F), 9925 kPa (1280 psia) enters the tube side of the molten salt heat exchanger where it is partially desuperheated by heating the salt flowing in the shell side. The salt flow is adjusted to maintain a constant steam outlet temperature. The steam then enters a spray desuperheater where its temperature is further reduced by mixing with and evaporation of feedwater. The feedwater flow rate is regulated to maintain a constant steam temperature of 600 K (620° F) into the vertical, hydrocarbon oil heat exchanger. At this steam temperature, the oil in the shell of the heat exchanger is protected from excessive film temperatures that would result in a high rate of thermal degradation. In the vertical heat exchanger, the steam is condensed in the tubes and heats the oil. The oil flow rate is controlled so that a constant pressure is maintained in the top head of the heat exchanger. The condensate collects in the bottom head of the vertical heat exchanger and then flows into a third exchanger where it is subcooled by the oil. The subcooling heat exchanger is sized so that the maximum temperature of the condensate exiting from thermal storage will be 539 K (510° F). Flow of condensate out of thermal storage is adjusted to maintain a constant liquid level in the condensing heat exchanger.

During discharge of thermal storage, the water, steam and storage media flows are reversed. The same heat exchangers are used during both the charging and discharging operations and this aspect of system operation constitutes the only unusual feature of the Thermal Storage Subsystem design. The storage system cannot be charged and discharged simultaneously, but this limitation does not impose a penalty on the operation of the total Central Receiver Solar Thermal Power System. Simultaneous charging and discharging of thermal storage is not expected to be a normal operation in the total solar plant.

In the discharge mode of operation, feedwater enters the horizontal oil heat exchanger and is preheated by the oil to just below the boiling point. The inlet feedwater temperature into thermal storage will vary as a function of the power output level of Electric Power Generation Subsystem, but a constant feedwater temperature into the vertical oil heat exchanger is maintained by regulating oil flow through the preheater with a bypass valve and a throttle valve in the preheater oil supply line. The feedwater is evaporated in the tubes of the vertical heat exchanger by hot oil in the shell. The oil flow rate, which determines the rate of evaporation, is adjusted to maintain a constant turbine inlet pressure. Feedwater will be admitted into thermal storage to maintain a constant water level in the top head of the evaporator. Steam generated in the evaporator passes through a dryer in the top of the head and then into the salt heat exchanger where it is superheated. The salt flow is adjusted to maintain a constant steam outlet temperature of 700 K (800° F).

Some of the control circuits are analogous to circuits used in the operation of conventional power plants. During charging, the condensing steam pressure is controlled by the oil flow rate; analogous to the operation of a turbine condenser in which the cooling water flow rate is regulated to maintain a constant turbine back-pressure. During discharging, the outlet pressure from thermal storage is controlled by oil flow rate. This control mechanism is equivalent to adjusting the fuel burning rate to control outlet pressure in a conventional boiler. A three-element feedwater regulator which is used in conventional boilers to control the water level will be used in the Thermal Storage Subsystem during discharge for the same purpose.

Figure VI-3 shows a heat balance for the two-stage thermal storage subsystem. The uppermost line represents the temperature potential of the charging steam as a function of the energy removed from it; likewise the lowest line represents the temperature of the steam discharged as a function of the energy added. The temperatures along these lines are established by the physical properties of water and the pressures selected for system operation. If the pressures are fixed, the Thermal Storage Subsystem must extract energy from steam represented by the upper line and supply energy to steam represented by the lower line. This diagram therefore defines the temperature limits that are imposed on the heat storage media by heat transfer and thermodynamic considerations.

The diagram resembles a temperature vs. enthalpy diagram. In fact, the graph for the discharging steam and the oil and molten salt lines do represent temperature-enthalpy curves. The charging steam curve has been slightly modified to account for the fact that the enthalpy change per kilogram of steam is slightly different during charging and discharging. To obtain the correct enthalpy change per kilogram of charging steam, it is necessary to divide the enthalpy change read from the graph by the ratio of kilograms of charging steam required for each kilogram of discharge steam. Since the ratio is 1.034 and very close to 1.0, it is safe to neglect the difference unless a very accurate heat balance is required.

The detailed schematic of the Thermal Storage Subsystem, shown in Figure VI-4, illustrates the scope of the equipment required more accurately than the conceptual schematic given earlier. Each of the stages incorporates multiple tanks, with one empty tank. The fluid in a full tank is pumped through a heat exchanger into the empty tank. The tank that has just been emptied then serves as the receiving reservoir for the next full tank. This system minimized the empty tank capacity in each stage, but required a flexible manifold and valve arrangement. A nitrogen blanket is incorporated in each stage in order to extend the life of the thermal storage fluids.

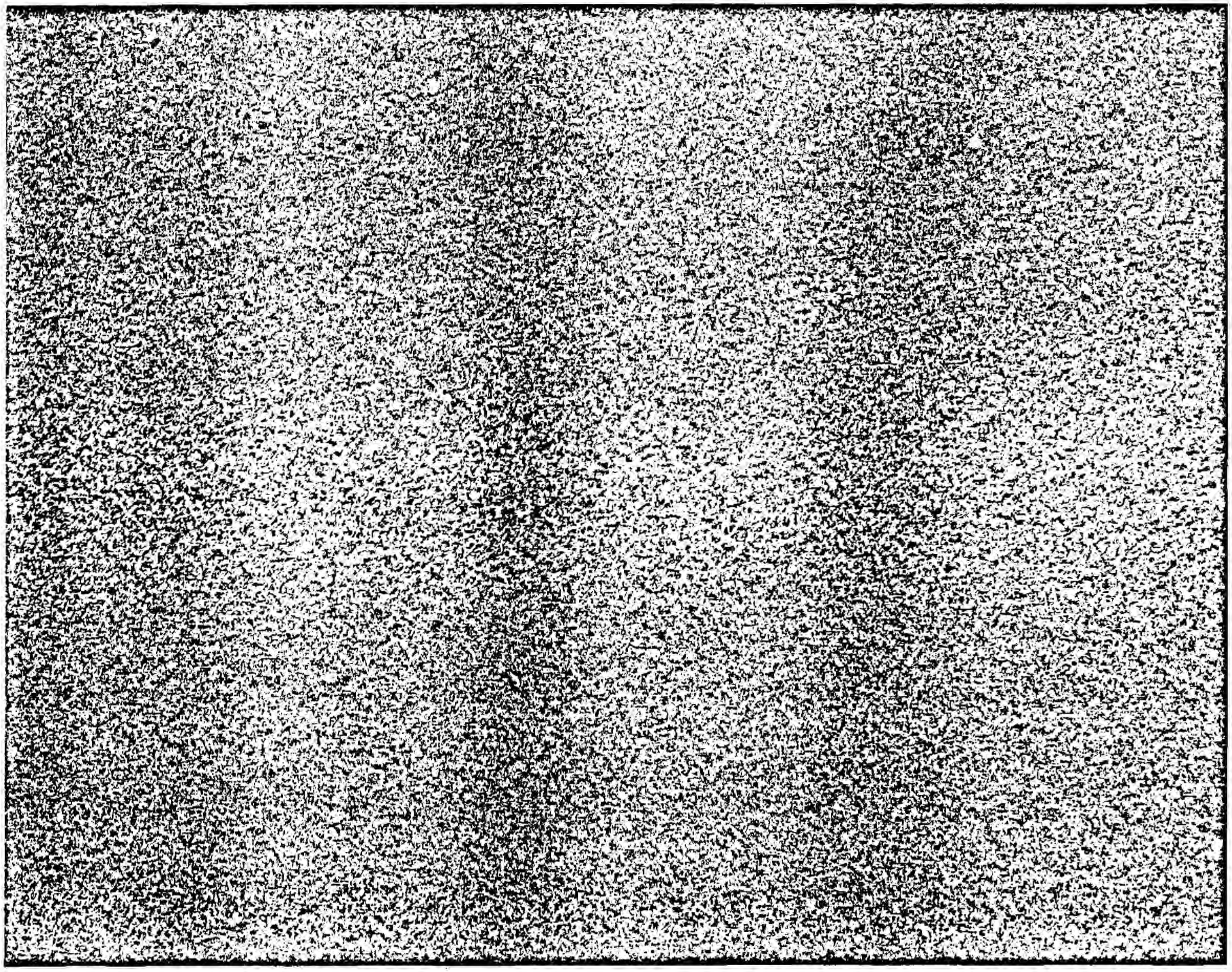


Figure VI-4. Detailed Schematic for Two-Stage Pilot Plant Thermal Storage Subsystem.

The preliminary layout in Figure VI-5 of the Pilot Plant Thermal Storage Subsystem includes all major components properly sized and all piping and valves that are shown on the detailed schematic. It has been partially optimized with respect to placement of equipment, although it is recognized that further optimization can be accomplished.

The molten salt and hydrocarbon storage media have been segregated to comply with safety codes and the energy transfer modules, including heat exchangers, pumps and associated equipment, have been grouped separately from the tanks. The land area required for this design is a rectangular plot approximately 275 by 250 feet (2.2 acres). The codes that apply to the Pilot Plant and Research Experiment Storage Systems are listed in Table VI-3. These code affect not only the general layout of the storage systems but the details of design as well. The extent of the coverage is indicated in the table. To date no deviations from these codes are foreseen in either the Pilot Plant or Research Experiment.

Three tanks for molten salt have been provided, any one of which is capable of holding the entire salt inventory; the rationale for this selection was to allow two working tanks and one spare which would be used if repairs were necessary. Three large tanks for hydrocarbon oil are shown, two of which are needed to hold the oil inventory; because of the large volume of fluid required in the condensing/evaporating stage, the tanks must be used to contain both hot and cool oil at different times, depending on the level of system charge. The nitrogen cover gas systems are incorporated in the ground layout.

4. <u>Storage Media Selection</u>

The storage media used in the Thermal Storage Subsystem had to have thermal properties that were compatible with the requirements for storage already outlined. In selecting the storage fluids, the following criteria were considered:

- o The operating temperature range of the media,
- o The heat capacity or specific heat,
- o The cost effectiveness of the material as a heat storage medium,
- o Hazards associated with handling and use, and
- o Performance of the material in industrial applications.

Hydrocarbon oils proved to be the most attractive candidates for the low temperature stage storage medium. Both synthetic oils and heat transfer oil obtained from the distillation of crude oil were considered.

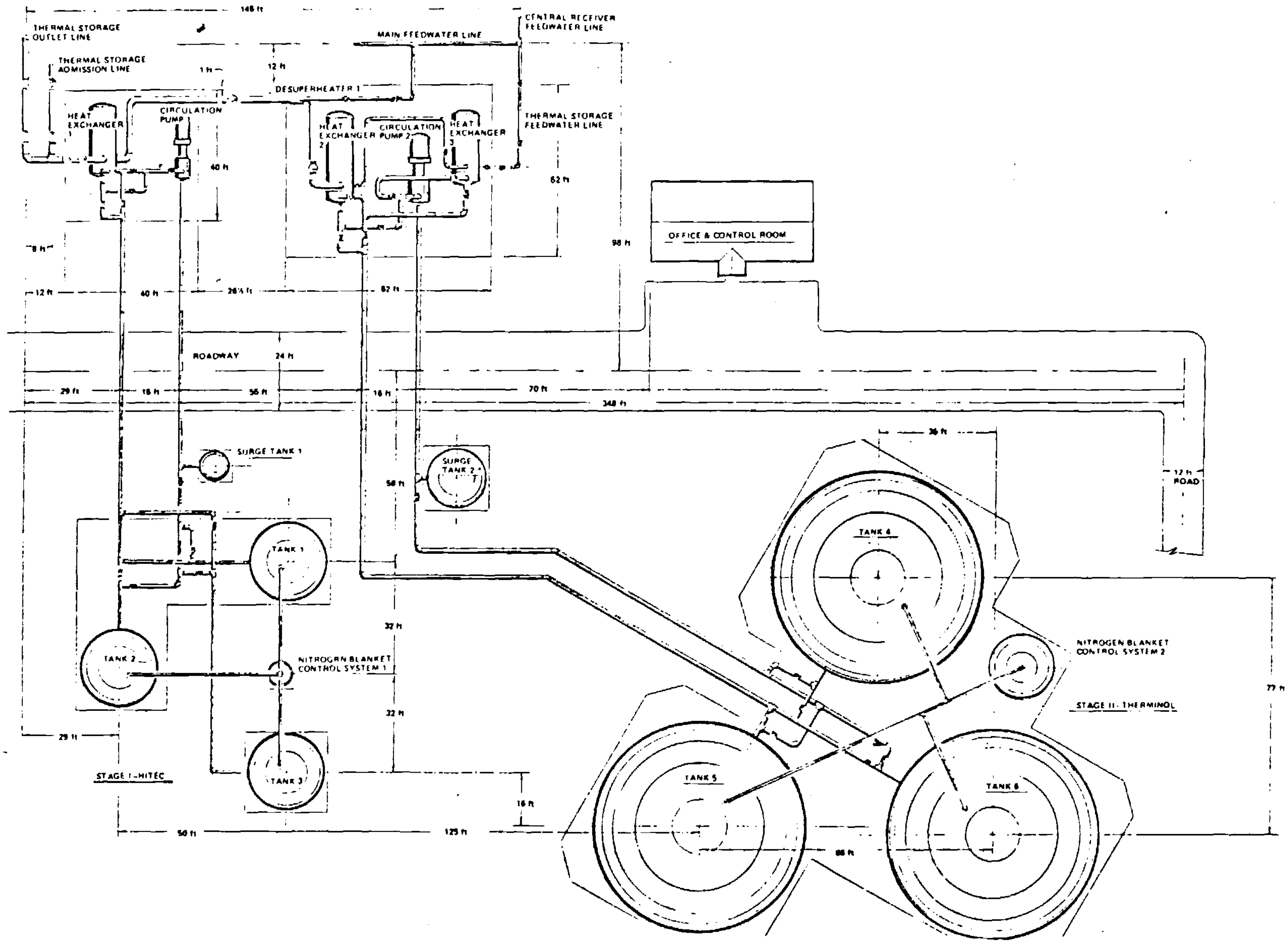


Figure VI-5. Preliminary Ground Layout for Two-Stage Pilot Plant Thermal Storage Subsystem.

TABLE VI-3

SUMMARY OF DOCUMENTS AND DESIGN COVERAGE AREAS APPLICABLE TO THE DESIGN OF THE PILOT PLANT AND RESEARCH EXPERIMENT THERMAL STORAGE SUBSYSTEMS

Document	Coverage
(1) American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (1974)	
SECTION II Material Specifications	Material specifications for materials used in the construction of the pressure vessels and storage tanks and all materials used as welding rods, electrodes and filler materials
SECTION V Nondestructive Examination	Nondestructive examination methods specified and utilized on all equipment and components
SECTION VIII Pressure Vessels - Division I	Heat exchangers and storage tanks
SECTION IX Welding & Brazing Qualifications	Welding and brazing requirements
(2) American National Standards Institute	
ANSI A58.1-1972 Building Code Requirements for Minimum Design Loads in Buildings and other Structures	Wind and earthquake loading
ANSI B31.1-1971 Power Piping Code	Steam and condensate/water piping. Molten salt and petroleum oil piping (all loading designs).
ANSI B31.3-1973 Petroleum Refinery Piping	Molten salt and petroleum oil piping (construction only)
(3) National Fire Protection Assn.	
Volume 2 (15-73) Water Spray Fixed Systems	Fire protection systems
Volume 3 (30-73) Flammable & Combustible Liquids Code	All elements of the thermal storage tankage design and layout not covered by ASME and ANSI
Volume 5 (69-73) Explosion Prevention Systems	Storage tankage explosion prevention system (inerting)
Volume 6 (70-75) National Electrical Code	All electrical circuits
(4) Standards of American Institute of Steel Construction and American Concrete Inst.	All structural steel design not provided for otherwise above and all structural concrete
(5) Department of Labor, Occupational Safety and Health Standards, FR-39-125 (June 27, 1974)	All aspects of personnel safety and health as applicable
(6) Uniform Building Code	All designs not provided for otherwise above
(7) Interstate Commerce Commission Shipping Standards and Regulations	As applicable

Table VI-4 contains a partial listing of the oils that were investigated along with some of their pertinent properties. The narrow-cut distillation fraction oils appear to be more cost effective than the synthetic oils. However, the synthetic oils are more stable chemically. It is presently anticipated that one of the cheaper oils will be used in the Pilot Plant, but the final decision depends on the results of the oil studies that are now being conducted. A detailed description of this study is found in a later section of this chapter.

TABLE VI-4

ROOM TEMPERATURE PROPERTIES AND PRICE FOR BULK QUANTITIES OF HYDROCARBON OIL

Oil Trade Name	Density	Capacity	Cost	
	kg/m^3	J/kg K	Dollars/m^3	Dollars/Gallon
Amoco Oil 4199	880	1943	266.81	1.01
Gulf Security 53	878	1943	250.96	.95
Shell Thermia 33	865	1926	219.26	.83
EXXON Caloria HT43	855	2177	258.89	.98
Therminol 55	887	1884	396.26	1.50
Therminol 66	1001	1449	1505.77	5.70

An inorganic salt was chosen as the storage medium for the high temperature stage. The salt is a eutectic mixture of $NaNO_2$, $NaNO_3$ and KNO_3 with a melting point of 415 K (288° F). The salt is variously called HITEC, Dupont's tradename for the mixture, and Heat Transfer Salt (HTS), the generic name for the same salt mixture. Heat Transfer Salt has a density of 1746 kg/m^3 (109 lb/ft^3) and a specific heat of 1562 J/kg K (0.373 Btu/lb-°F). The cost of the salt ranges from 84¢/kg (38¢/lb) to 46¢/kg (21¢/lb). The lowest cost results from buying the individual chemical components and mixing the salt at the plant site. HTS has been used in industrial applications since the 1930's, and its physical and chemical properties are well documented. The salt has been operated at temperatures of up to 727 K (850° F) in low carbon steel systems and up to 810 K (1000° F) in stainless steel process equipment.

5. <u>Pilot Plant Performance Studies</u>

A computer model of the Thermal Storage Subsystem was developed in order to:

1) Better understand the operating characteristics of the Thermal Storage Subsystem, and

2) Simplify scaling of Research Experiments results to Pilot Plant performance predictions.

The partial differential equations describing the transient flow of heat and fluids in the thermal storage subsystem were solved using finite difference routines contained in MITAS. MITAS (Martin Marietta Interactive Thermal Analysis System) is a multipurpose computing program. A physical description of heat flow in the Thermal Storage Subsystem is entered into MITAS by establishing the boundary conditions and by constructing a thermal analog network of the system. Individual capacitances in this network are sized according to the thermal storage capabilities of quantized, elemental sections of the heat exchangers and storage tanks. Conductances in the network define the flow of thermal energy between the elemental sections and the ambient environment. Differential fluid flow expressions are introduced into MITAS via logic portions of the program that are an integral part of the solution of the thermal analog network. These logic sections are also utilized in simulating the action of the operating controls which stabilize the overall storage subsystem during transient charge or discharge conditions.

Models were made of thermal storage for both the Pilot Plant and the Research Experiment. The graphs in Figures VI-6 and VI-7 are typical examples of results obtained from the MITAS simulations. The steam and feedwater outlet temperatures from the spray desuperheater and heat exchangers for a charging operation are shown in the figures; Figure VI-6 is for the Pilot Plant and Figure VI-7 is for the Research Experiment. In both simulations, a step increase in steam flow from zero to the nominal flow rate is imposed on the model. The temperatures in the desuperheater and subcooler behave as expected and after an initial damped oscillation level off to a steady temperature. The temperature reaches steady state after about 10 minutes following a sudden startup. The outlet temperature from the condenser, in both models, displays a periodic oscillation but this oscillation has been traced to a deficiency in the analytical model. Further refinement of the model is expected to eliminate the temperature oscillation and permit accurate prediction of system behavior.

These preliminary predictions illustrate the capability of the computer model to describe system performance. After further improvements, including more sophisticated simulation of control functions, the computer model will be employed to predict system performance under all anticipated

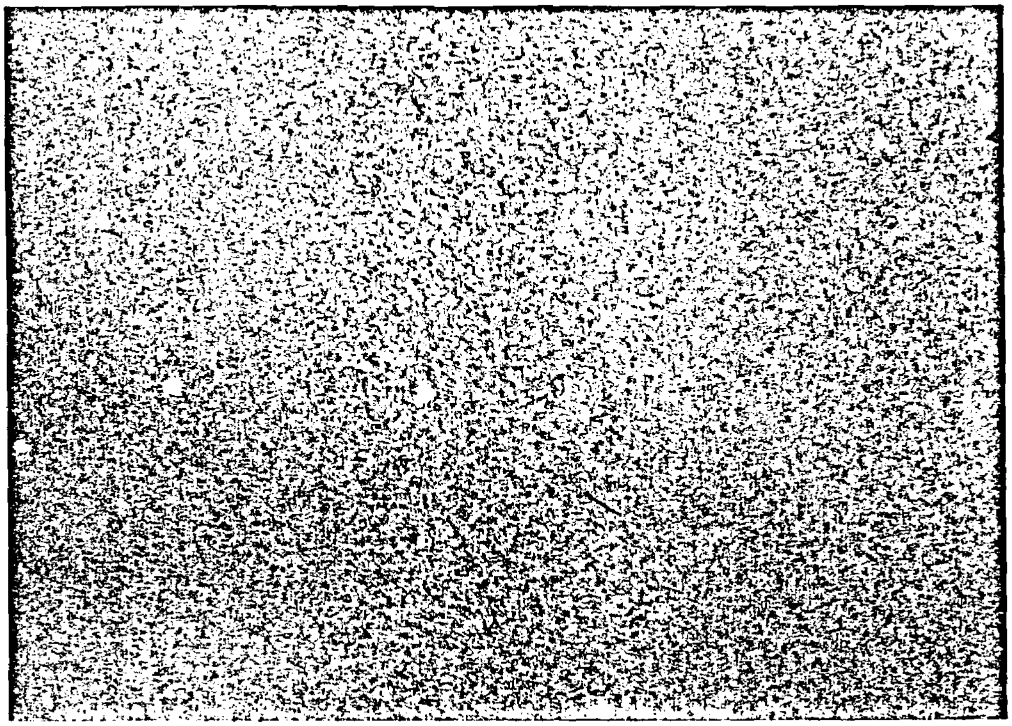


Figure VI-6. Predicted Steam and Water Outlet Temperatures for Pilot Plant Thermal Storage Subsystem during Charging.

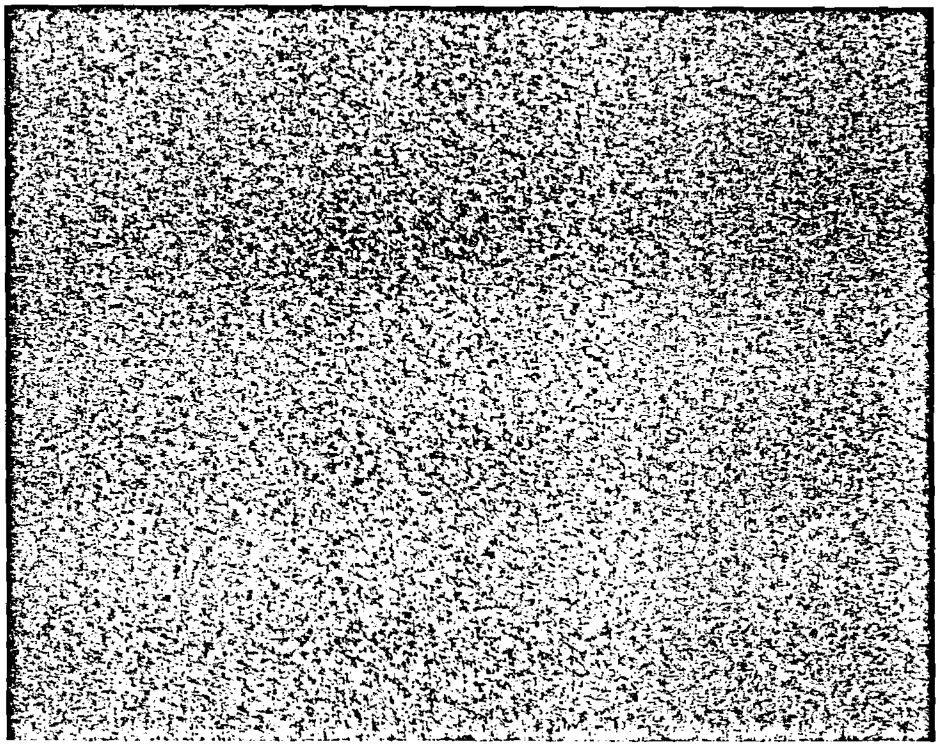


Figure VI-7. Predicted Steam and Water Outlet Temperatures for Research Experiment Thermal Storage Subsystem during Charging.

operating conditions; for example, change from one operating mode to another, receipt of variable steam flow rates from the receiver, following turbine loads in a demand mode, etc.

C. THE THERMAL STORAGE SUBSYSTEM RESEARCH EXPERIMENT

The Research Experiment is designed to demonstrate the technical feasibility of the selected thermal storage concept. It is a miniature Pilot Plant Thermal Storage Subsystem in all important respects except flow rate and capacity, which will require scaling to the Pilot Plant levels. It matches the Pilot Plant with respect to steam and water state points, storage materials, operating temperatures and handling methods, control systems, and operating strategy.

1. Research Experiment Requirements

The Research Experiment is designed to meet the following requirements:

- Accept superheated steam in the CHARGE MODE at 8619 kPa (1250 psig) and 783 K (950° F); produce superheated steam in the DISCHARGE MODE at 4137 kPa (600 psig) at 672 K (750° F).
- Function in the CHARGE AND DISCHARGE MODES at
  - A maximum rate of 2.0 MWth and a minimum rate of 0.4 MWth
  - Any intermediate rate between the maximum and minimum
  - Varying rates which simulate the anticipated characteristics of the Pilot Plant Receiver and Electric Power Generation Subsystems.
- Demonstrate the suitability of commercially available control systems for control of the Thermal Storage Subsystem.
- Store in the CHARGE MODE sufficient energy to allow 1.6 MW h (thermal) to be recovered in the steam supplied in the DISCHARGE MODE.
- Provide performance data suitable for correlation to design predictions.
- Establish design criteria and performance expectancies for the Pilot Plant Thermal Storage Subsystem.

2. Description of the Thermal Storage Subsystem Research Experiment

A detailed schematic of the Thermal Storage Subsystem Research Experiment is shown in Figure VI-8. It is analogous to the conceptual schematic shown in Figure VI-2, but includes control loops and additional piping details which were omitted from Figure VI-2; the heat balance diagram shown in Figure VI-3 applies also to the system defined by Figure VI-8.

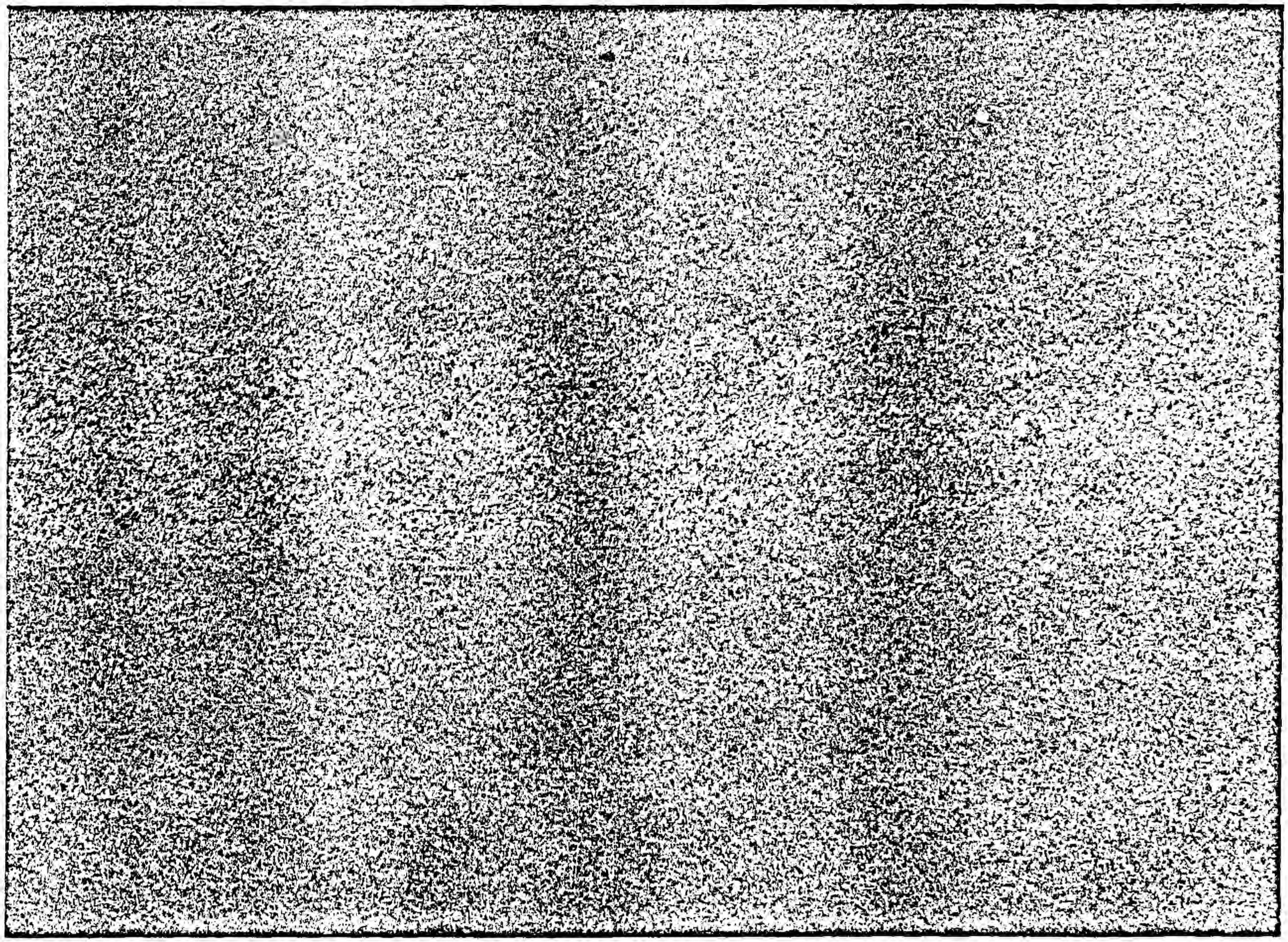


Figure VI-8. Detailed Schematic of Thermal Storage Subsystem Research Experiment.

During charging, steam enters the Research Experiment at 783 K (950° F) and 8619 kPa (1250 psig) and is cooled to 626 K (667° F) in the heat transfer salt stage (heat exchanger HE1 and associated hardware). The remaining superheat in the steam is removed in the desuperheater DS2 and the steam passes to the condensing stage (heat exchanger HE2) where it is condensed at 574 K (574° F). The condensate is passed to the sub-cooling stage (heat exchanger HE3) where it is cooled to 539 K (510° F) and discharged to silencer S1. Desuperheaters DS1 and DS2 are water injection units provided to allow the steam temperatures to be reduced in order to protect the storage media from overheating under certain flow conditions. During operation in the charging mode the molten salt storage medium is pumped from the cold reservoir (tank T2) at 577 K (580° F) through heat exchanger HE1 to the hot reservoir (tank T1) at 727 K (850° F); the hydrocarbon oil storage medium is pumped from the cold reservoir (tank T4) at 531 K (497° F) through heat exchangers HE3 and HE2 to the hot reservoir (tank T3) at 570 K (567° F).

During discharging, all flow directions are reversed and the pressure in the steam-water sections of the system is changed. Feedwater enters the Research Experiment at 505 K (450° F) and 4137 kPa (600 psig), is preheated in the heat exchanger HE3, evaporated in the heat exchanger HE2 at 530 K (495° F), and superheated in heat exchanger HE1 to an output temperature of 672 K (750° F). The desuperheaters DS1 and DS2 are not used in the discharge mode. A shunting loop around heat exchanger HE3 is provided for the hydrocarbon oil through FRV 15 in order to balance the heat input and prevent boiling in HE3. The specified discharging rate of 2.0 MWth corresponds to a steam flow rate of 3267 kg/hr (7187 lb/hr).

The Research Experiment operation will virtually duplicate the Pilot Plant operation except in flow rates and energy storage capacity. The exception is the use of feedwater at a temperature of 505 K (450° F) in the Research Experiment rather than the temperature of 477 K (400° F) anticipated in the Pilot Plant.

The Research Experiment is currently being constructed at a site owned by the Georgia Power Company at its Plant Yates, a coal-fired steam electric generating installation near Newnan, Georgia. This location was selected because superheated steam could be obtained at conditions matching the Pilot Plant receiver output state points, and the temperature levels throughout the Research Experiment could thus match very closely those expected in the Pilot Plant. The Georgia Power Company is supplying superheated steam, treated feedwater, other utilities and land; the program will pay for these services under a subcontract with the company.

A perspective drawing of the Thermal Storage Subsystem Research Experiment is shown in Figure VI-9 and a recent photograph of the experiment under construction is shown in Figure VI-10. The two smaller tanks are the

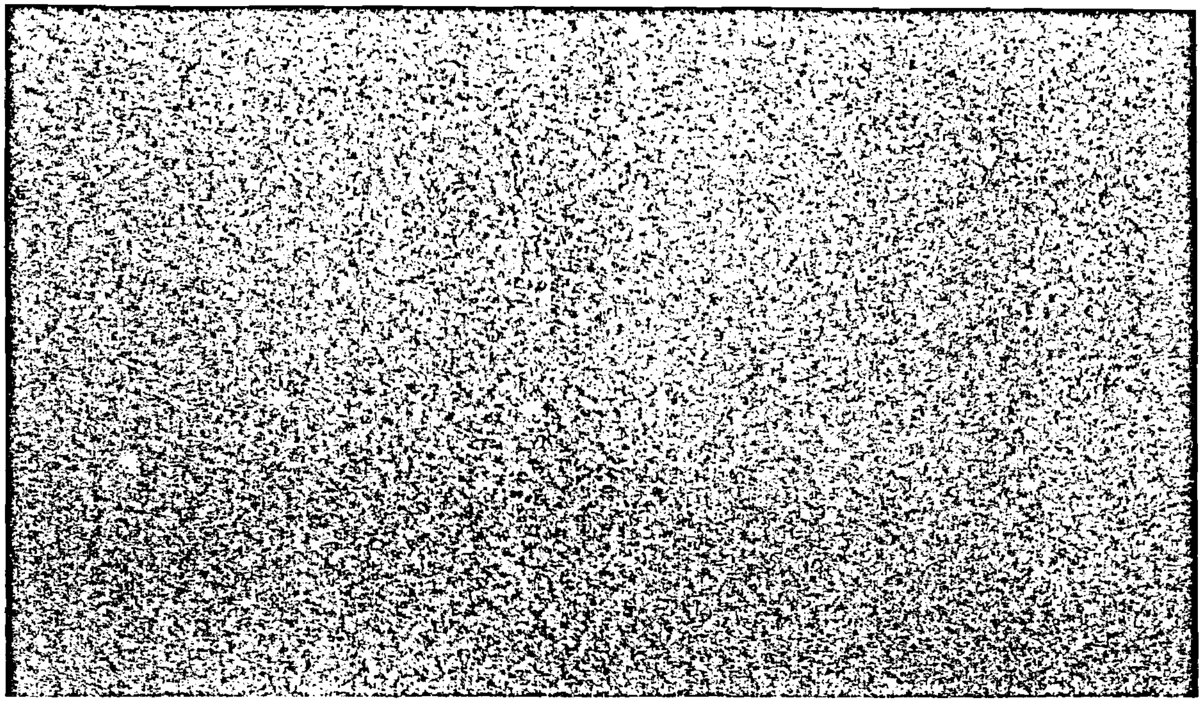


Figure VI-9. Perspective View of Thermal Storage Subsystem Research Experiment, without Supporting Structures.

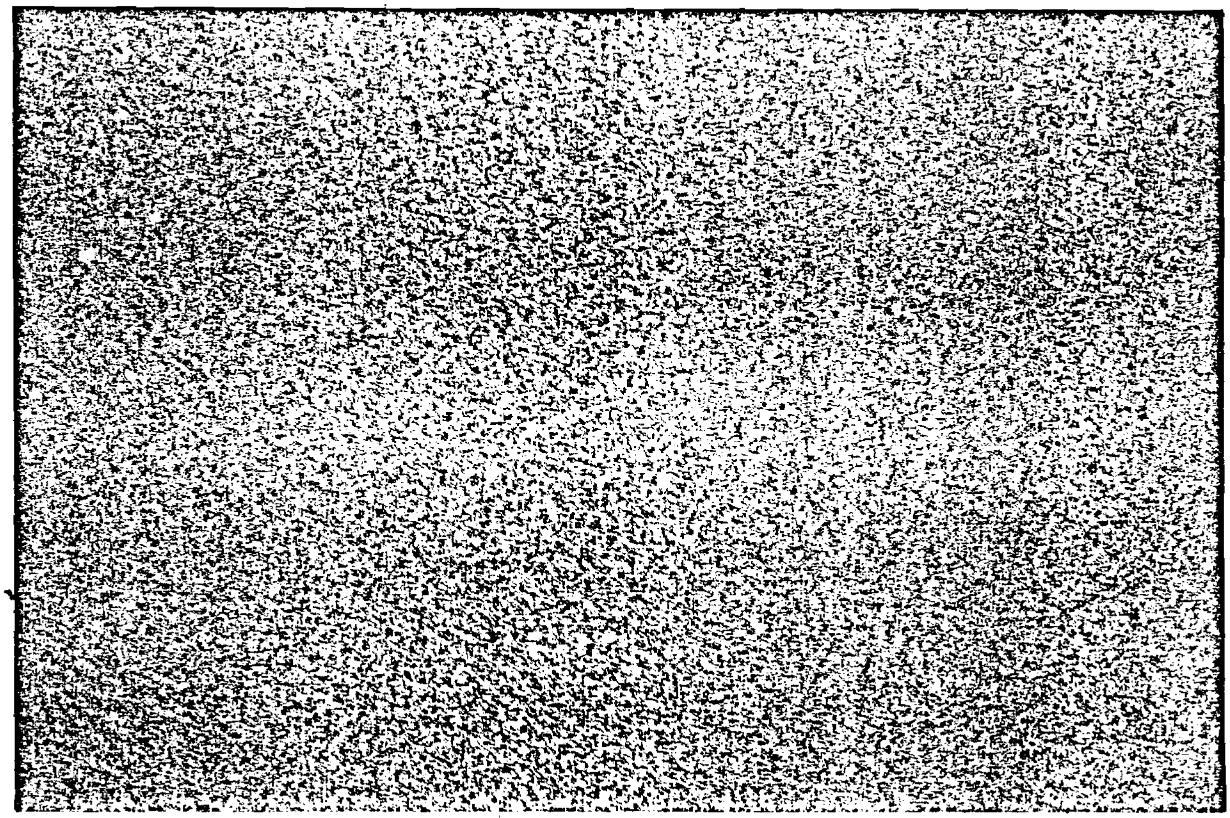


Figure VI-10. View of Thermal Storage Subsystem Research Experiment under Construction.

molten salt storage reservoirs; the heat exchanger assembly mounted between these tanks is the desuperheating-superheating exchanger HE1. The large vertically-oriented heat exchanger is the condensing-evaporating exchanger HE2, and the small horizontally-oriented heat exchanger behind HE2 is the subcooling-preheating exchanger HE3. The two larger tanks in the background are the oil storage reservoirs and the control trailer can be seen on the left in Figure VI-10. A ground layout of the Research Experiment is shown in Figure VI-11, illustrating the placement of the major items of equipment.

Figure VI-12 shows the Research Experiment heat exchangers and pipe trestle on which the steam and water lines are supported. The superheated steam and treated feedwater are supplied from a nearby generating unit and are carried along the trestle to a point adjacent to the desuperheating-superheating heat exchanger.

The heat exchangers are shown in Figures VI-13 through VI-18 and described in Table VI-5. All heat exchangers are tube-in-shell designs and perform dual functions; heat is transferred to the storage fluids during charging and from the storage fluids during discharging. In order to provide the thermal driving force needed for system operation, the pressure on the steam-water side of the exchangers is 8619 kPa (1250 psig) during charging and 4137 kPa (600 psig) during discharging. During charging, the water level in the condensing-evaporating exchanger HE2 is maintained near the bottom of the unit and steam condensation occurs; during discharging, this water level is maintained near the top of the unit and boiling occurs. The desuperheating-superheating heat exchanger HE1 was constructed as two series-operated units to accommodate the large changes in fluid temperatures between the respective inlets and outlets.

The storage media tanks are shown in Figures VI-19 through VI-22 and described in Table VI-6. The salt tanks are provided with submerged steam coils to permit melting of the heat transfer salt after it is placed in the tanks and to permit the salt to be held above its melting temperature during prolonged shutdown periods. The salt tanks in the Research Experiment were fabricated from carbon steel because their operating lifetimes are expected to be only a few months; stainless steel has tentatively been selected for use in a Pilot Plant.

The storage media pumps are described in Table VI-7. The oil pump is a conventional design and is mounted outside the tanks. However, the salt pumps are a submerged design with the electric motor mounted on a flange at the top of the tank and the pumping head submerged in the molten salt near the bottom of the tank. Submerged pumps are required for pumping the molten salt at the temperature levels in the Research Experiment because reliable shaft seals are not available. In a Pilot Plant Thermal Storage Subsystem the salt pumps would be a cantilevered design without submerged bearings or seals. In this case, the pumps might be installed in sumps rather than in the tanks themselves because tank heights would require prohibitively long cantilevered pump shafts.

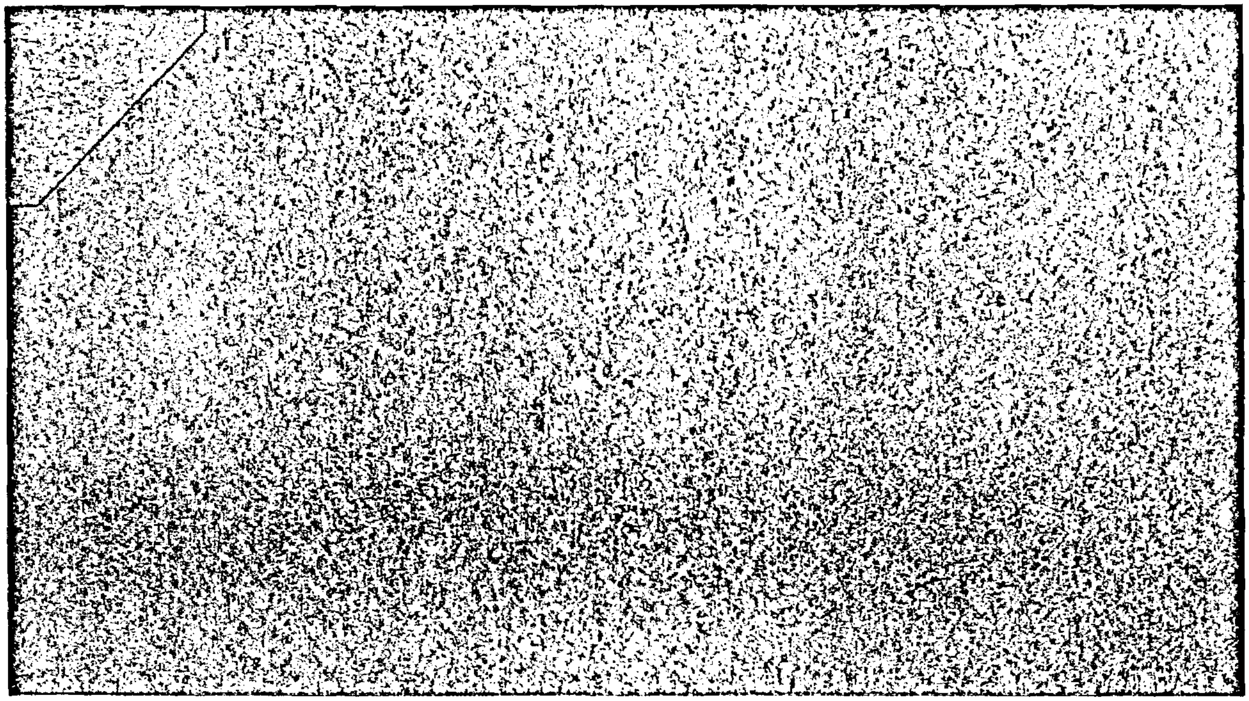


Figure VI-11. Ground Layout of Thermal Storage Subsystem Research Experiment.

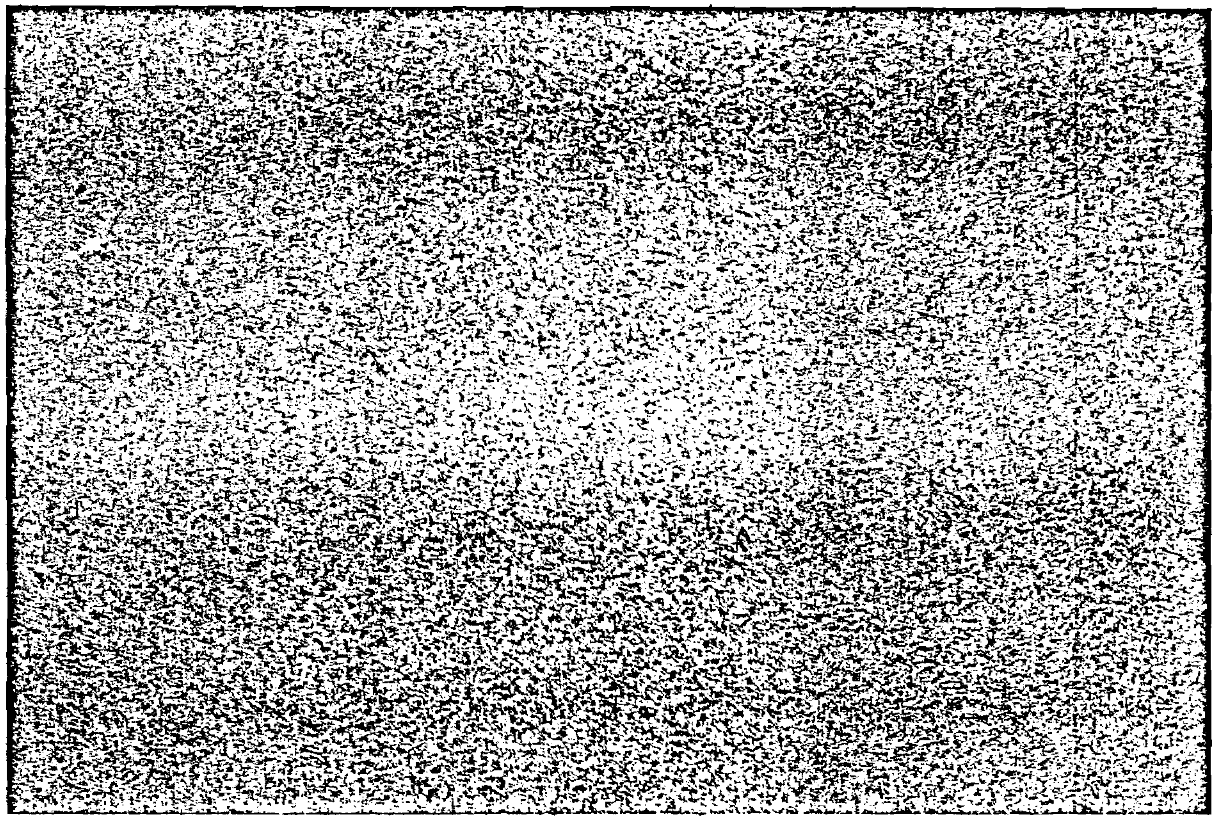


Figure VI-12. View of Pipe Trestle and Heat Exchangers in Thermal Storage Subsystem Research Experiment.

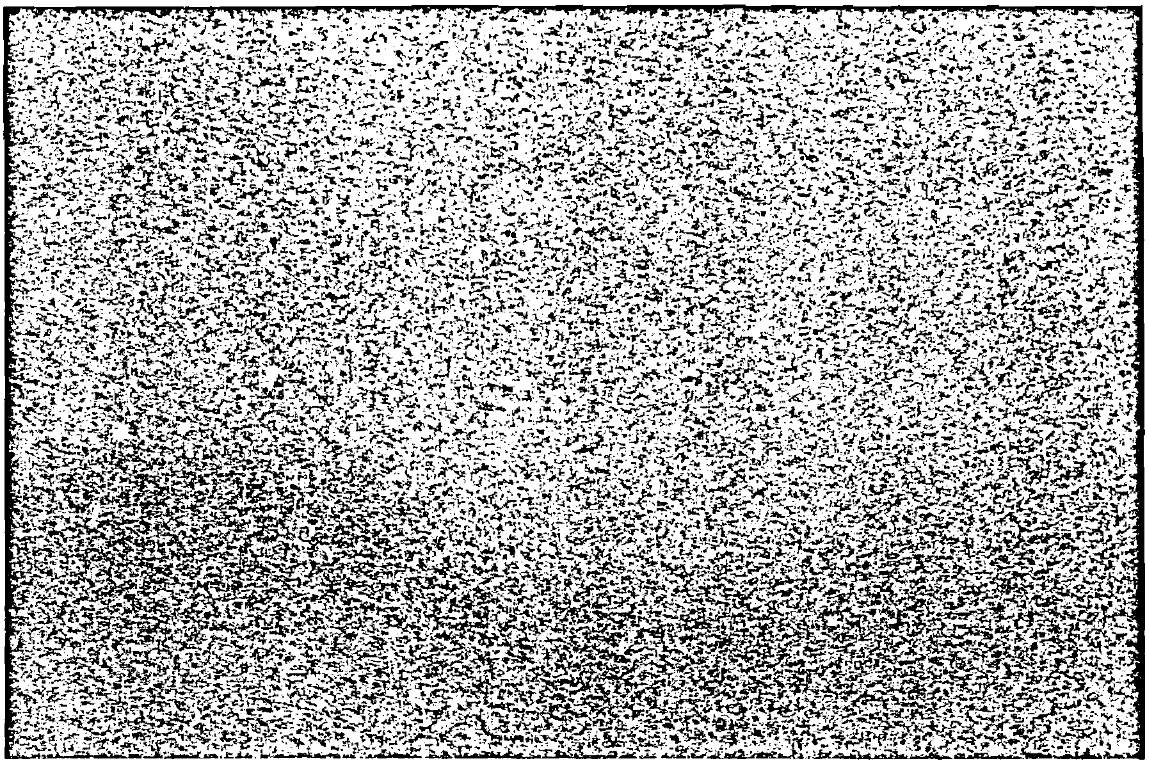


Figure VI-13. Desuperheating-Superheating Heat Exchanger HE1 Drawing.

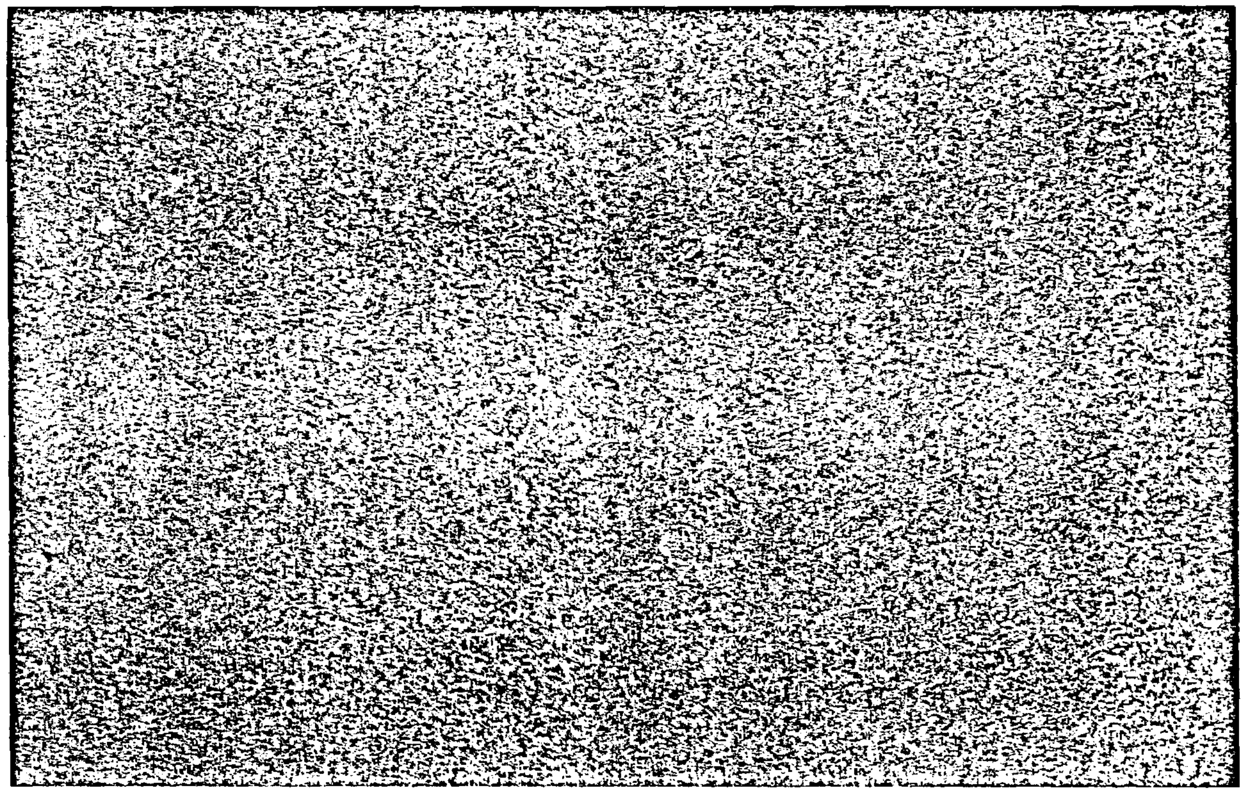


Figure VI-14. Desuperheating-Superheating Heat Exchanger HE1.

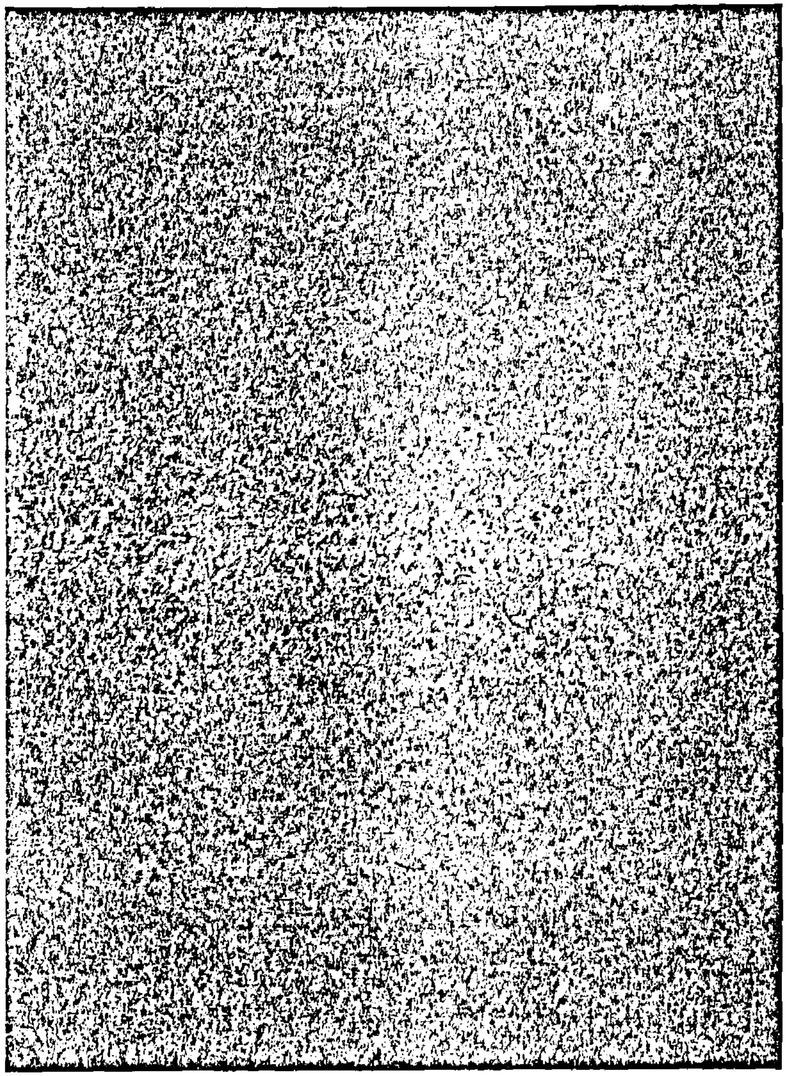


Figure VI-15. Condensing-Evaporating Heat Exchanger HE2.

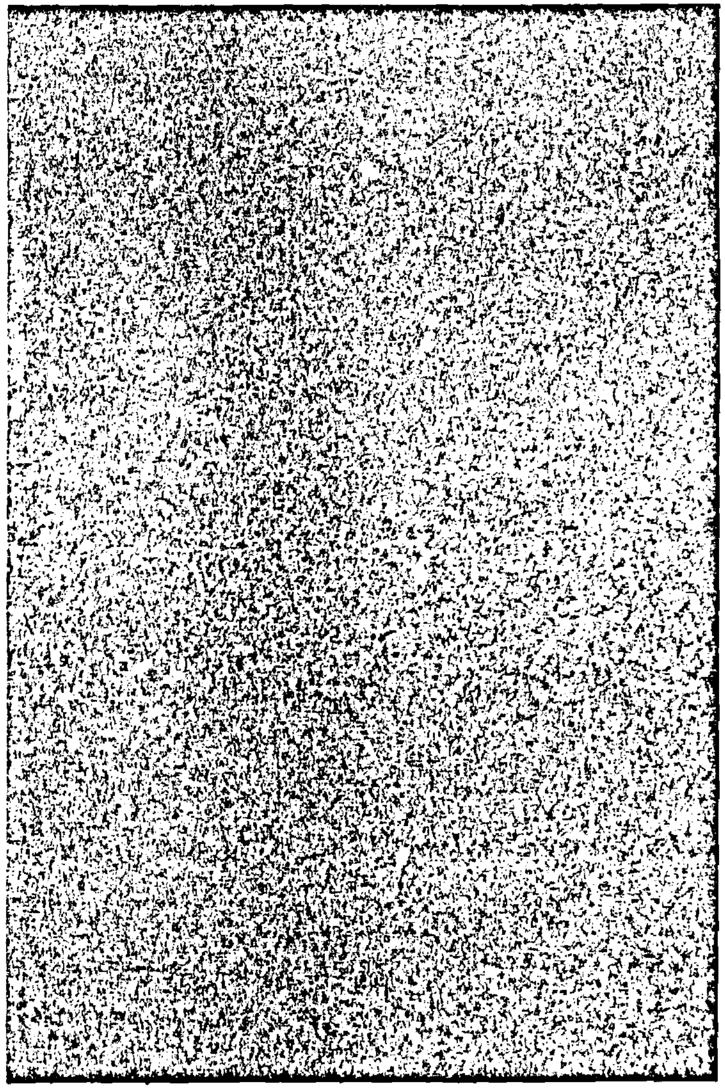


Figure VI-16. Condensing-Evaporating Heat Exchanger HE2 Drawing.

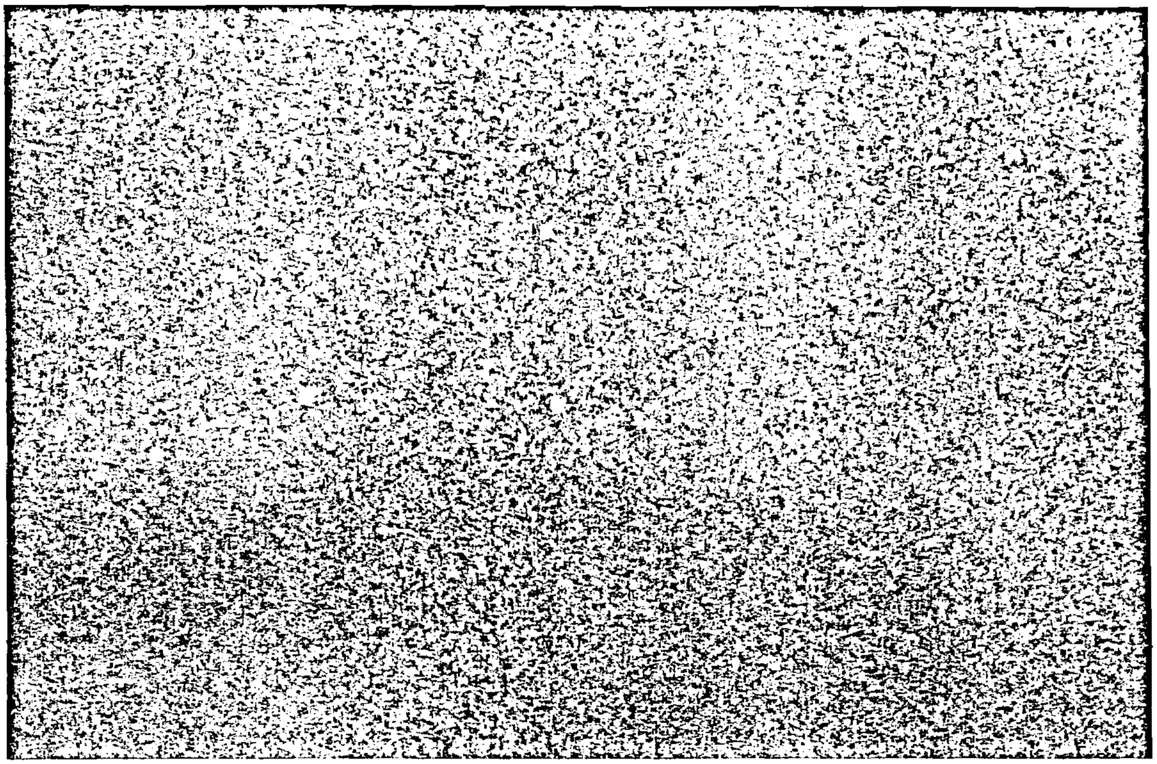


Figure VI-17. Subcooling-Preheating Heat Exchanger HE3 Drawing.

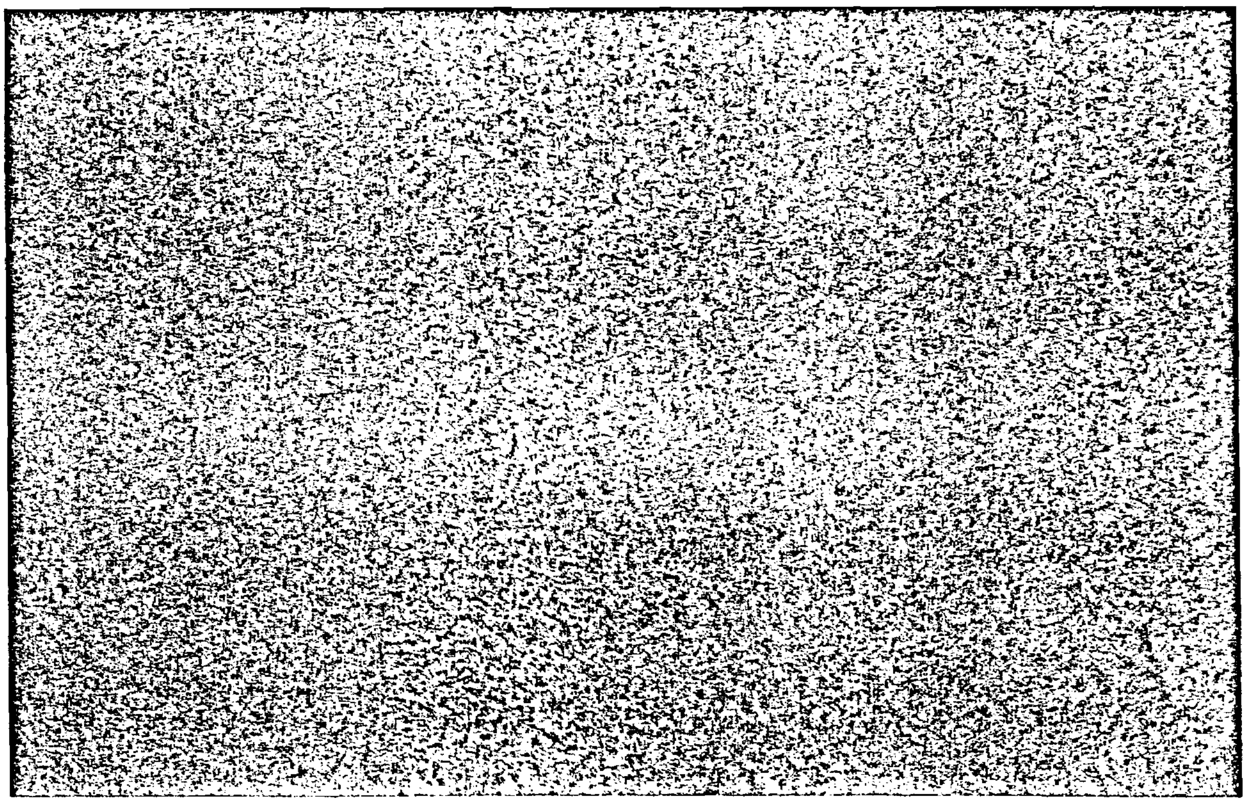


Figure VI-18. Subcooling-Preheating Heat Exchanger HE3.

TABLE VI-5

HEAT EXCHANGER DESCRIPTION AND SPECIFICATIONS

Parameter	HE1	HE2	HE3
Description	Two U-tube, tube-in-shell bundles; mounted horizontally and operated in series	One fixed tube sheet, tube-in-shell bundle; mounted vertically and operated as a condenser during charging and as and evaporator during discharging	One U-tube, tube-in shell bundle; mounted horizontally
Heat exchange area m^2 (ft^2)	43.8 (471)	321.8 (3464)	33.2 (357)
Material	alloy steel	carbon steel	carbon steel
Shell diameter m (in.)	0.356 (14)	0.508 (20)	0.254 (10)
Shell length m (ft)	3.048 (10)	7.315 (24)	3.658 (12)
Number of tubes	60 per unit	301	30
Tube description	0.01905 m (0.75 in.) diameter; seamless	0.01905 m (0.75 in.) diameter; low fin, seamless	0.01905 m (0.75 in.) diameter; low- fin, seamless
Supplier	THERMXCHANGER, Inc., Oakland, California		

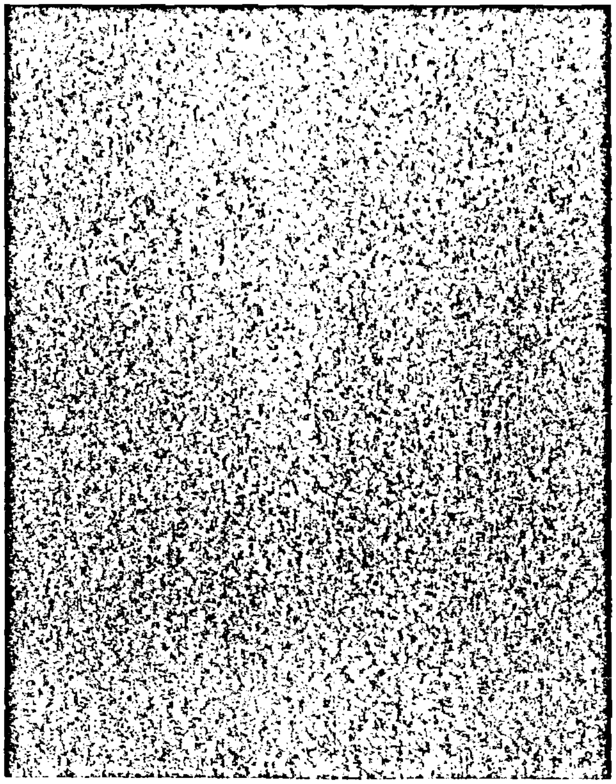


Figure VI-19. Drawing for Molten Salt Storage Tank.

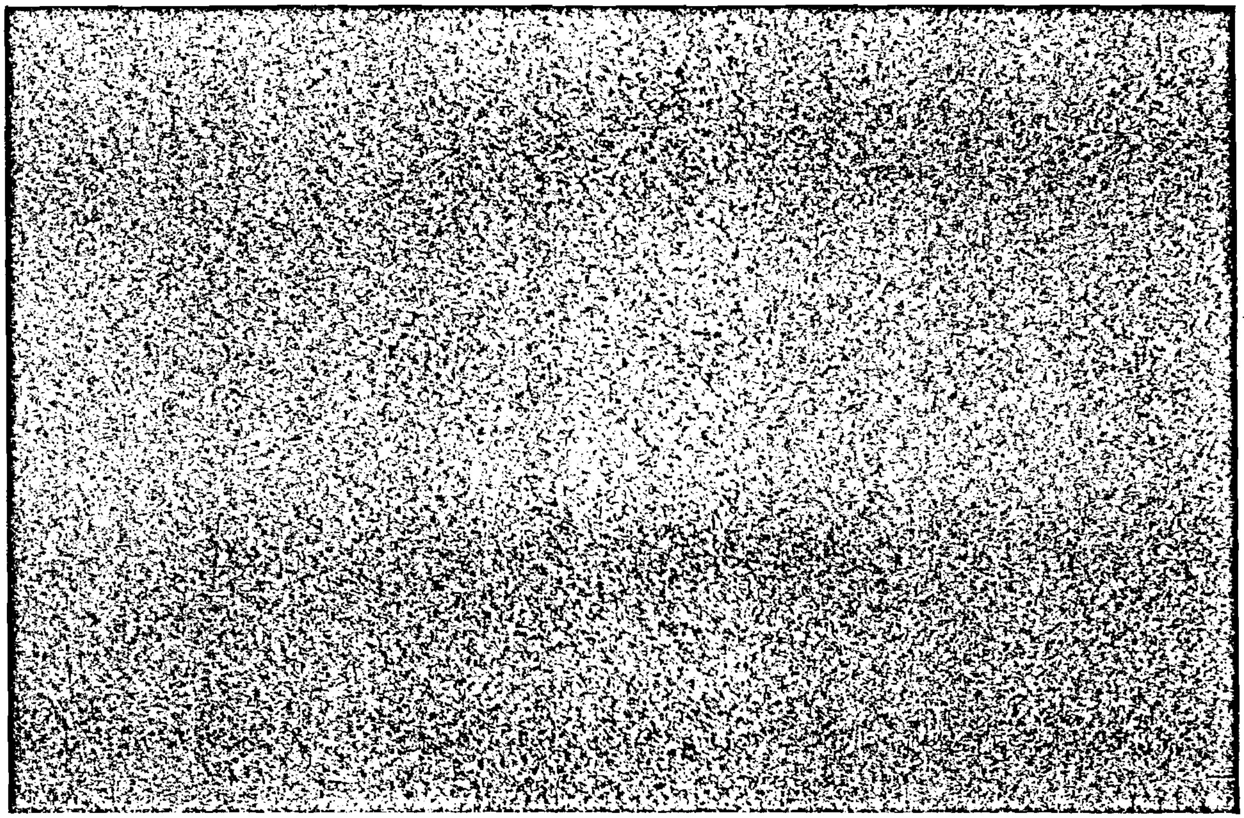


Figure VI-20. Molten Salt Storage Tanks and Heat Exchanger HE1.

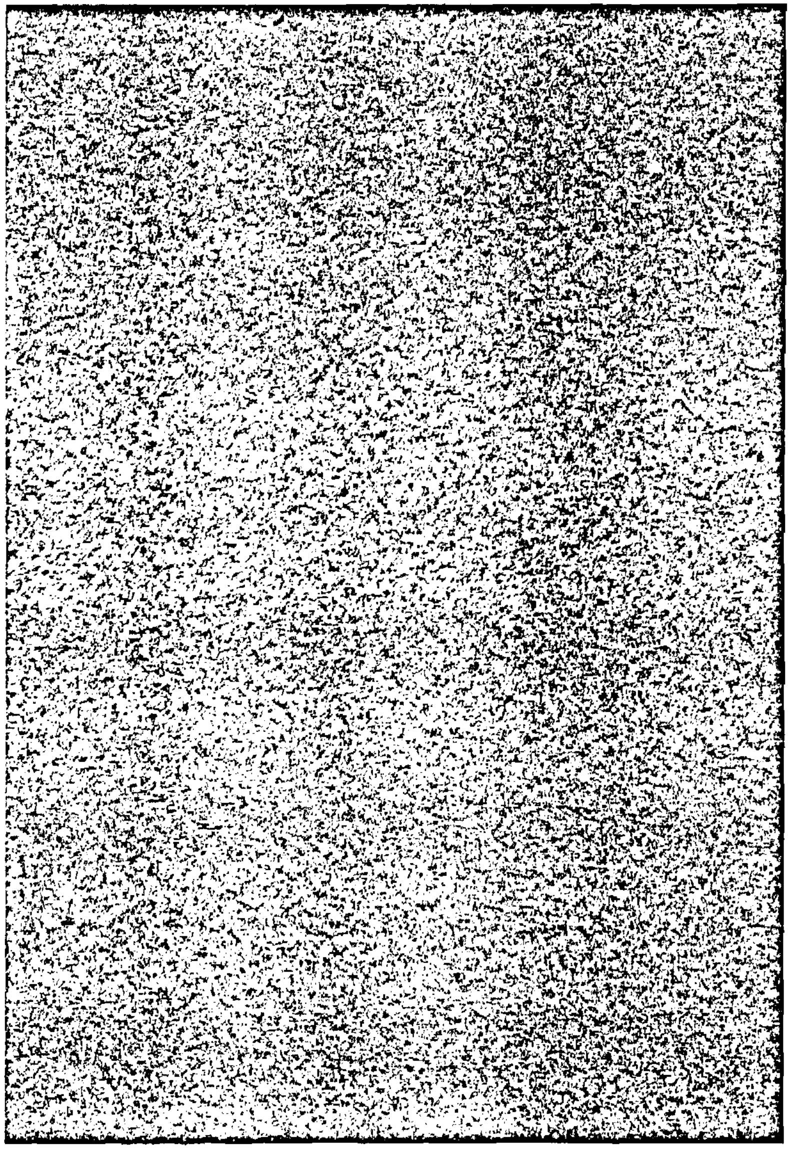


Figure VI-21. Hydrocarbon Oil Storage Tank.

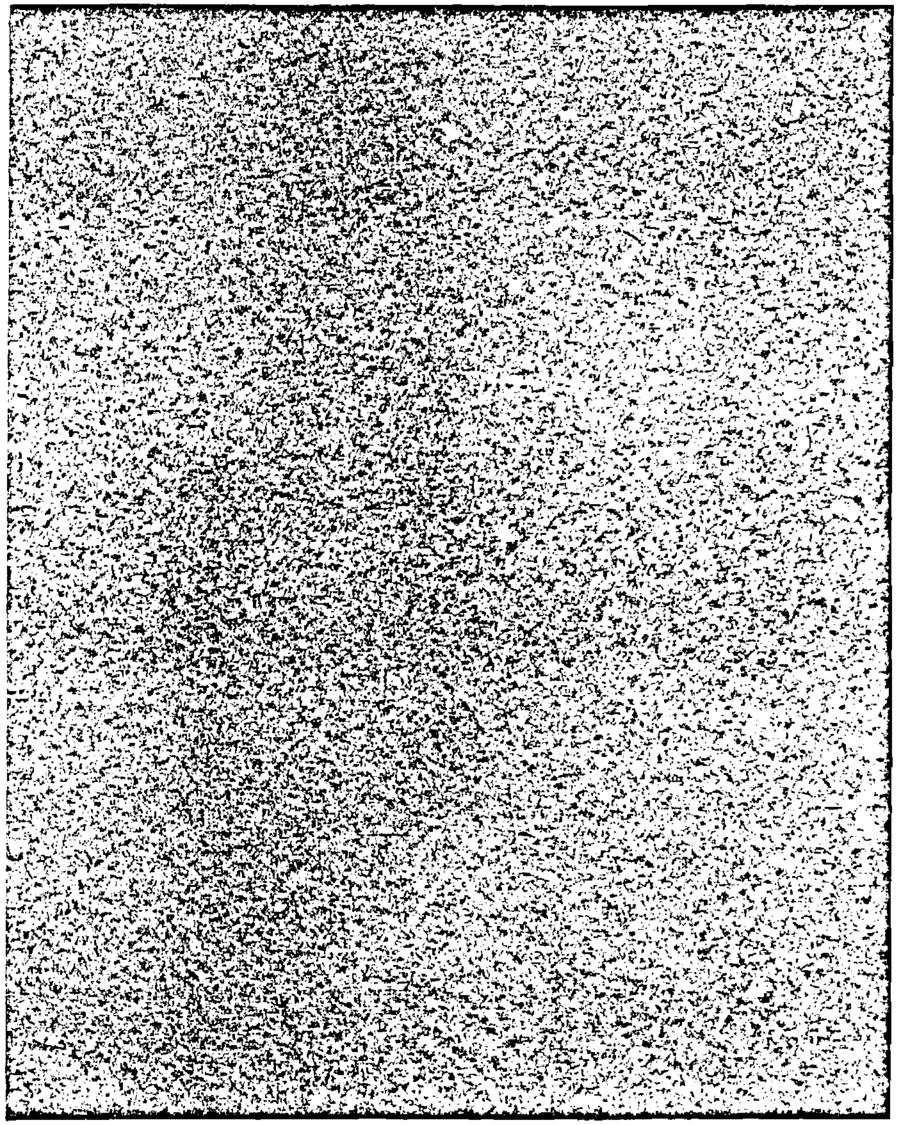


Figure VI-22. Drawing of Oil Storage Tank.

TABLE VI-6

STORAGE TANK DESCRIPTION AND SPECIFICATIONS

Parameter	Salt Tanks	Oil Tanks
Description	Two cylindrical tanks; vertically mounted with submerged pumps placed near bottom of tanks; ASME flanged and dished heads	Two cylindrical tanks; vertically mounted; ASME flanged and dished heads
Liquid and nominal capacity kg (lbs)	Heat transfer salt; 6,636 (14,629)	Heat transfer oil (hydrocarbon oil); 59,380 (130,910)
Nominal and maximum operating temps. K (^{o}F)	722 (840); 755 (900)	570 (567); 580 (585)
Material	carbon steel, welded construction	carbon steel, welded construction
Tank diameter m (ft)	1.83 (6)	3.66 (12)
Over-the-heads dimension m (ft)	2.06 (6.75)	9.30 (30.5)
Total tank volume m^3 (ft^3)	4.6 (162)	90.6 (3,200)
Supplier	J. J. Finnigan Industries, Inc., Duluth, Georgia	

TABLE VI-7

PUMP SPECIFICATIONS AND SUPPLIERS

Parameter	CP-1 & 2	CP-3
Storage Fluid Circulated	Heat transfer salt (molten)	Heat transfer oil (hydrocarbon oil)
Pump Type	Centrifugal, single stage	Centrifugal, single stage
Mounting	Vertical, tank mounted	Horizontal, base mounted
Casing Material	Stainless steel	Cast steel
Impeller Material	Stainless steel	Cast iron
Rated Drive Power, kW (hp)	3.73 (5)	22.37 (30)
Speed, rad/s (rpm)	183 (1750)	366 (3500)
Rated Capacity, liter/s (gpm)	1.14 (18)	25.23 (400)
Total Developed Head, m (ft)	21.34 (70)	76.20 (250)
Pump Size, Discharge x Suction mm (in.)	38.1 x 50.8 (1.5 x 2)	76.2 x 101.6 (3 x 4)
Supplier	Lawrence Pump and Engine Co. Lawrence, Massachusetts	Dean Brothers Pumps, Inc. Indianapolis, Indiana

Figure VI-23 shows a plan view of the oil piping system to illustrate the scope of the piping designs. After the pipe lines were sized and components located, the piping design procedure called for tentative location of lines using hand-calculation routines, followed by computation of stresses using a commercial computer program known as PIPESD; the tentative designs were then iterated until stresses fell within allowable limits.

Figure VI-24 shows a drawing of the spray desuperheaters DS1 and DS2. These units spray feedwater into the superheated steam in order to reduce its temperature. The desuperheaters are unusual in that they must operate over a wide range of flow rates and must allow flow in both directions with acceptable pressure drops; they are used while steam is flowing in only one direction, during operation in the charging mode. The desuperheaters are mounted vertically with steam flowing up during desuperheating and the water is injected countercurrent to the direction of steam flow.

The Research Experiment control panel is shown in Figures VI-25 and VI-26. This equipment is mounted in the control trailer adjacent to the Research Experiment and provides process control and the capacity for simulation of flow rates from the Receiver Subsystem and to the Electric Power Generation Subsystem.

3. Research Experiment Test Plan and Procedures

The Test Plan for the Research Experiment was published on June 28, 1976. The Test Plan describes the test objectives, the planned test sequence, the test site, instrumentation and controls, crew organization and safety requirements.

The objectives, which are grouped into primary and secondary catagories in the Test Plan, can be summarized as follows:

Primary Objectives -

1) Demonstrate that the Research Experiment hardware is capable of charging and discharging thermal energy into and out of the liquid storage media at the desired system temperatures, pressures and rates.

2) Demonstrate that the Research Experiment controls can maintain the required operating parameters at different steam flow rates and during transients.

3) Demonstrate that the process equipment designs (heat exchangers, tanks and interconnecting piping) can tolerate anticipated thermal and pressure transients.

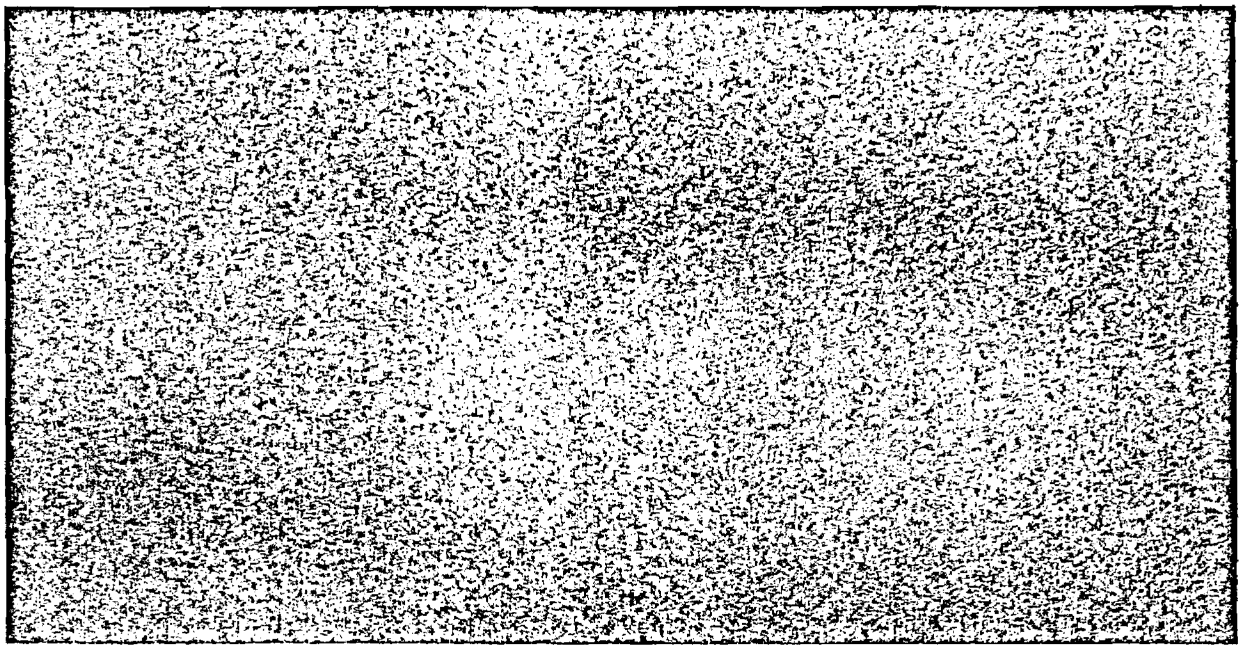


Figure VI-23. Plan View of Oil Piping System.

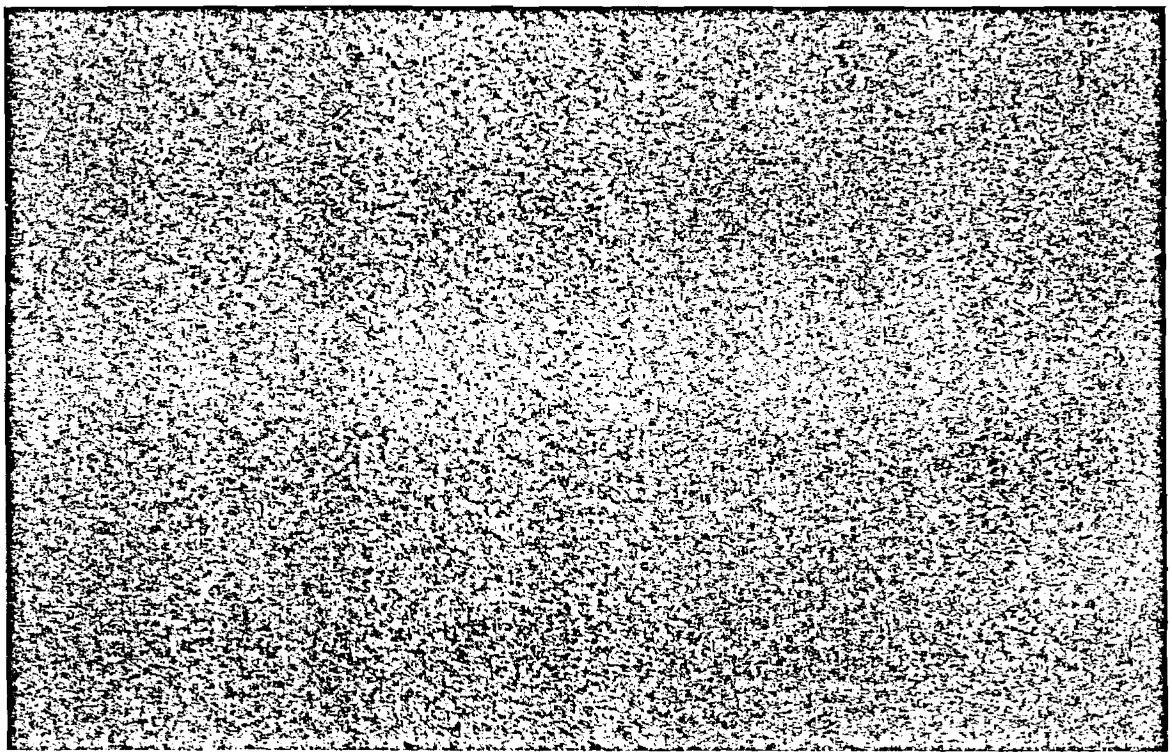


Figure VI-24. Desuperheating Drawing.

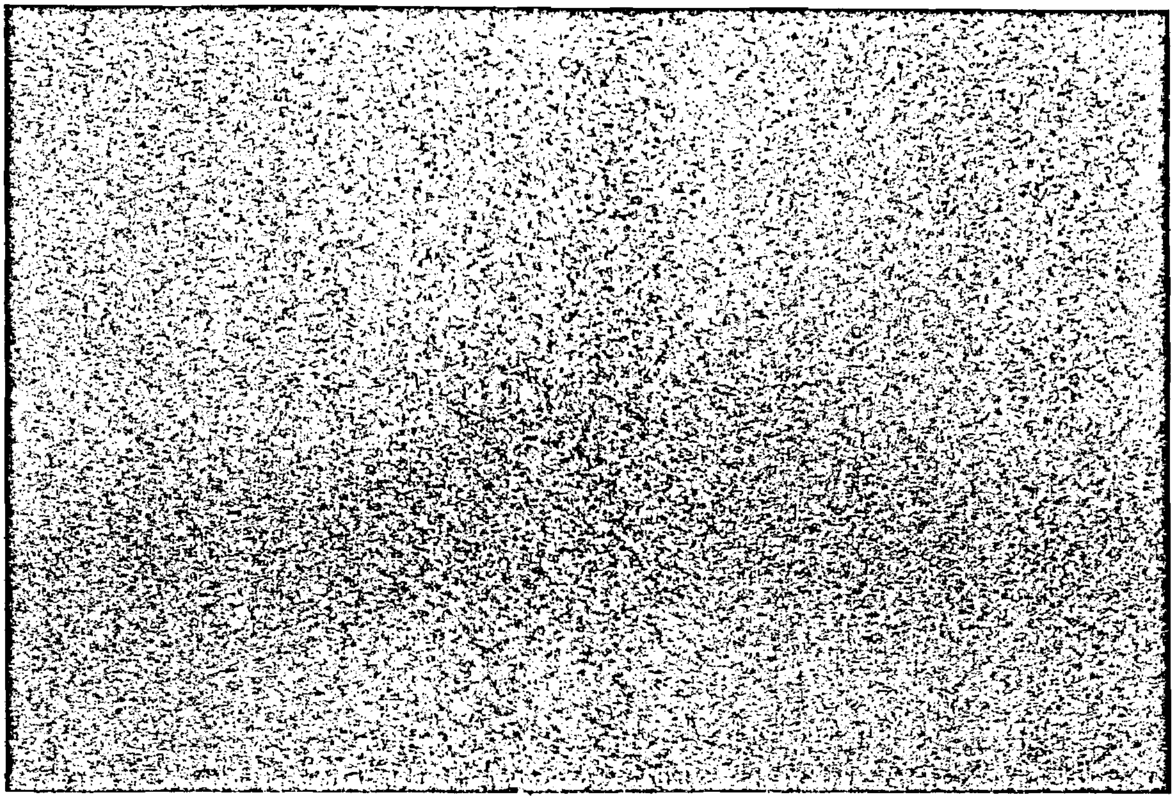


Figure VI-25. Drawing of Research Experiment Control Panel.

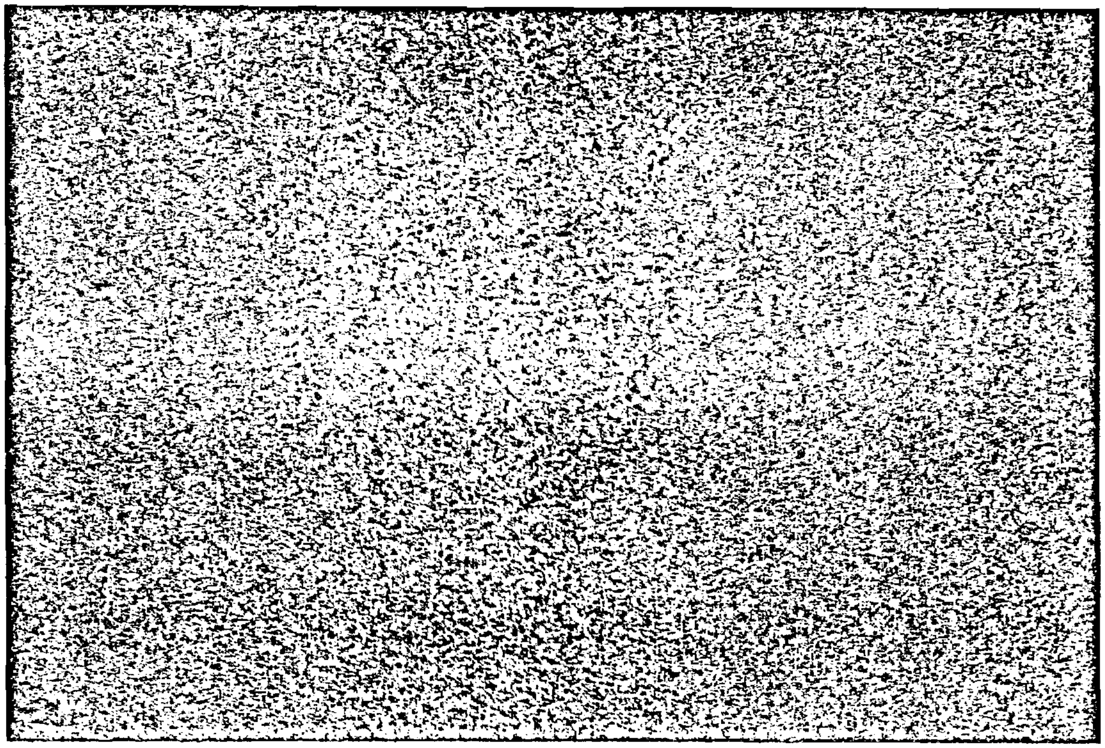


Figure VI-26. Research Experiment Control Panel.

4) Develop and demonstrate procedures for Pilot Plant initial charging and operation.

Secondary Objectives -

1) Develop control and operating experience with a Thermal Storage Subsystem of the planned design.

2) Experimentally establish system heat losses and their effect on the storage system efficiency.

3) Identify design deficiencies and corrections to be incorporated into the Pilot Plant Preliminary Design.

The test sequence starts with a series of preliminary tests. These tests are primarily for the purpose of system checkout and trouble-shooting, but also include the initial loading and heating of the storage media. After successful completion of the preliminary tests, the performance test sequence will begin. A brief outline of the performance tests is:

1) Constant rate charging and discharging operations in which the entire Thermal Storage Subsystem Research Experiment is completely charged and discharged at 50, 100, and 20 percent of the design steam flow rates.

2) Transient charging and discharging operations in which the Research Experiment is run in modes which simulate steady changes in power level and power level changes which follow anticipated Pilot Plant conditions.

During the performance test sequence, operating mode reversals and repitition of runs will be accomplished in order to demonstrate the capability of the system to respond to the demands of other Pilot Plant subsystems.

To ensure that the test operations are safe and productive, detailed test procedures have been written. The procedures are grouped into nine function-related chapters as indicated in Table VI-8. It was intended that the procedures include every action that is required to accomplish the specified task and any cautions or unusal circumstances that operators should be aware of during execution of the procedure. The procedures will be updated during the tests to incorporate changes suggested by operating experience.

4. Construction of Research Experiment

All of the components required for construction of the Research Experiment have been ordered and received. The major components have been described in this chapter. Broyles and Broyles, Inc., Atlanta Division, was

TABLE VI-8

RESEARCH EXPERIMENT DETAILED PROCEDURES

Chapter	Title	Scope of Procedures
1	Systems Descriptions	Standard System Operating Configurations
2	Initial System Preparation	Functional checks, loading of media, N_2 blankets
3	Startup Tests	Preheating, steam trace & heating, salt melting, blowdown, initial charge & discharge, shutdown
4	Component Handling	Water sampling & testing, changing N_2 tanks
5	Normal Operations	Steady state & transient charging & discharging operations, mode reversal, daily checks, manual operation, steam consumption
6	Emergency Conditions	Loss of controls, loss of steam, manual override, spillage, line rupture, fire, other emergencies
7	Disaster Plans	
8	Maintenance	
9	Electrical & Mechanical Tests	
10	Instrumentation Calibration	

selected to build the Research Experiment on a competitive bid basis and began work the week of July 12, 1976. To date, all major components have been set in place and the oil piping system has been completed and hydrotested. The molten salt piping and steam and feedwater piping are about 50 percent complete, and the contractor is maintaining the original construction schedule.

At the end of the construction phase, the steam and feedwater piping will be chemically cleaned. The cleaning operation will be performed by Halliburton Services through their Huntsville, Alabama office. The operation will consist of:

1) Degreasing with a 2 percent NaOH solution.

2) Descaling with an inhibited 3 percent hydroxyacetic-formic acid solution.

3) Rinsing and passivating with a $NaNO_2$ solution.

Cleaning is scheduled for the week of October 25, 1976. Immediately following the cleaning operation, the steam and feedwater piping will be hydrotested.

E. SCHEDULE FOR PROGRAM COMPLETION

The master schedule for the completion of the program is shown in Figure VI-28. The program is on schedule at this time and no significant delays or interruptions are foreseen. The Research Experiment test program will be in progress until mid-January and the Pilot Plant preliminary design will be conducted between that time and early April.

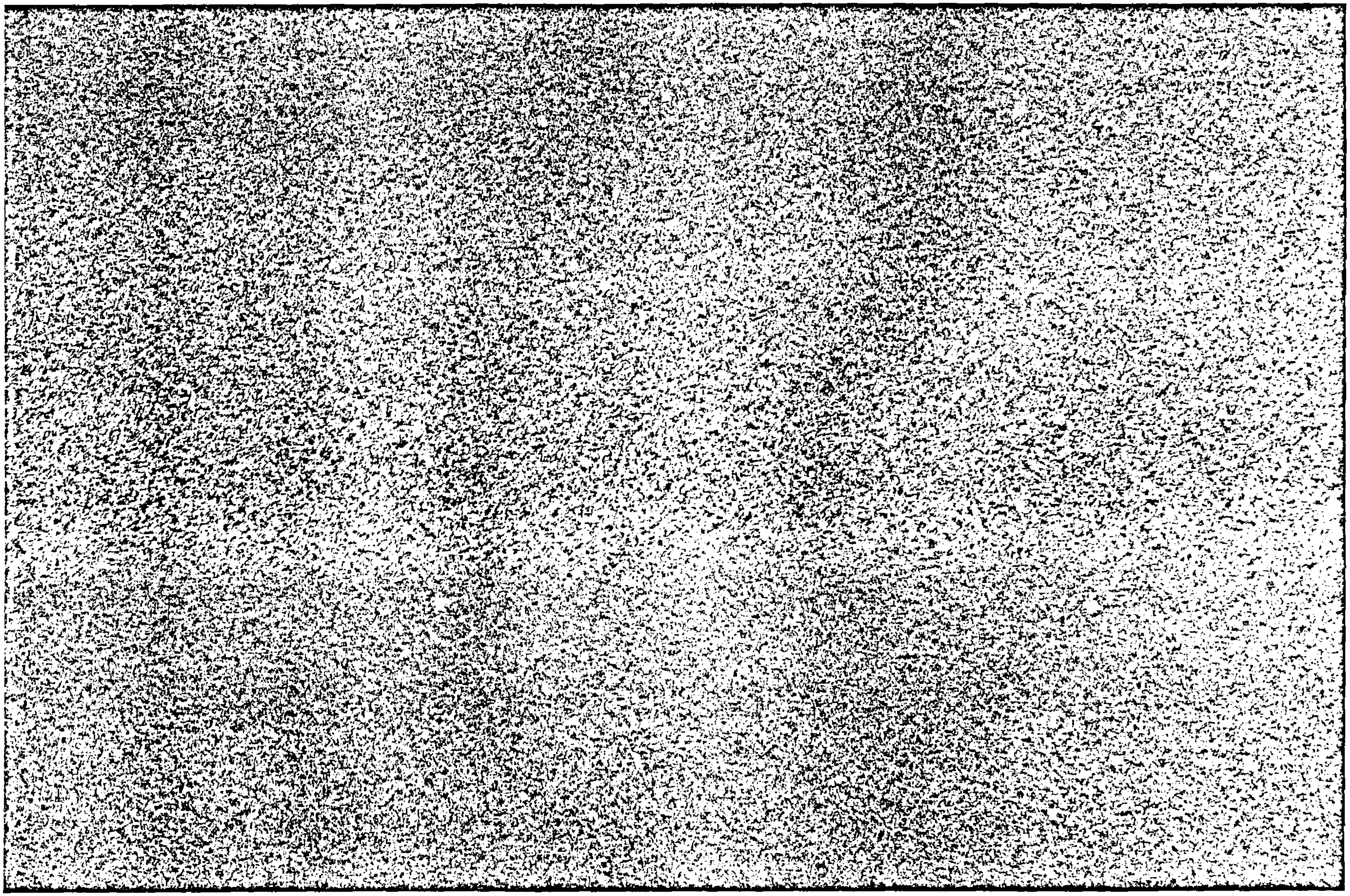


Figure VI-28. Thermal Storage Subsystem Master Schedule.

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

June 28, 1976

Martin Marietta Corporation
P. O. Box 2371
Denver, Colorado 80201

Attention: Mr. John E. Myers
Mail No. S-0403

Subject: Tranmittal of Georgia Tech Final Test Plan for Thermal Storage Subsystem Research Experiment under MMC Contract RC5-230340

Gentlemen:

Attached herewith is one (1) complete reproducible and one (1) copy of subject.

Please send copy to Mr. Ray Ernest.

Sincerely yours,

Carlos Seminario

Carlos Seminario
Program Operations Coordinator
Solar Energy and Materials
Technology Division

jw

Enclosure: One Reproducible and one copy of Georgia Tech Final Test Plan.

CENTRAL RECEIVER SOLAR THERMAL POWER SYSTEM, PHASE 1

FINAL TEST PLAN

THERMAL STORAGE SYBSYSTEM RESEARCH EXPERIMENT

Martin Marietta Corporation
Denver Division
Denver, Colorado 80201

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

June 28, 1976

Prepared by:

R. F. Altman
Georgia Institute of Technology

J. E. Myers
Martin Marietta Corporation

Approved by:

S. H. Bomar, Jr.
Georgia Institute of Technology

F. A. Blake
Martin Marietta Corporation

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1.0 GENERAL - This test plan specifies tests to be conducted on the Thermal Storage Subsystem Research Experiment hardware. The hardware is to be erected by a subcontractor at a site owned by the Georgia Power Company at Plant Yates, a coal-fired, steam electrical generation facility located near Newnan, Georgia about 50 miles southwest of Atlanta. The subcontractor, Broyles and Broyles, Inc., Atlanta Division, will perform certain acceptance tests, such as leak checking, before Georgia Tech assumes control of the hardware. Georgia Tech, with the assistance of personnel assigned by Martin Marietta, will then conduct the tests specified in this plan in order to meet the objectives given herein.

2.0 OBJECTIVES - The overall objectives of the Thermal Storage Subsystem Research Experiment tests are to demonstrate the technical feasibility of the thermal storage concept proposed by the Martin Marietta Pilot Plant research team and to identify design changes that should be incorporated into the Pilot Plant Preliminary Design. The specific objectives may be divided into two groups:

2.1 Primary Objectives - These must be accomplished during the test program in order to demonstrate feasibility and identify design changes:

a. Demonstrate that the Research Experiment hardware is capable of charging thermal energy into the liquid storage media at the desired system temperatures, pressures and rates by desuperheating and condensing the charging steam. The maximum and minimum rates and nominal temperatures and pressures are listed in Table 2.1.1.

TABLE 2.1.1

STEAM TEMPERATURES, PRESSURES AND FLOW RATES

1) CHARGING

MAXIMUM FLOW RATE		MINIMUM FLOW RATE		INCOMING STEAM TEMPERATURE		INCOMING STEAM PRESSURE		EXIT CONDENSATE TEMPERATURE	
(kg/hr)	(lb/hr)	(kg/hr)	(lb/hr)	(K)	(^{o}F)	(kPa)	(psig)	(K)	(^{o}F)
3247	7159	649	1432	783	950	8612	1250	538	510

2) DISCHARGING

MAXIMUM FLOW RATE		MINIMUM FLOW RATE		EXIT STEAM TEMPERATURE		EXIT STEAM PRESSURE		INCOMING FEEDWATER TEMPERATURE	
(kg/hr)	(lb/hr)	(kg/hr)	(lb/hr)	(K)	(^{o}F)	(kPa)	(psig)	(K)	(^{o}F)
3260	7187	652	1437	673	752	4364	633	505	450

b. Demonstrate that the Research Experiment hardware is capable of discharging thermal energy from the liquid storage media at the desired system temperatures, pressures and rates by evaporating and superheating the feedwater (see Table 2.1.1).

c. Demonstrate that the Research Experiment hardware can be controlled to maintain the required operating conditions while following a variable input steam rate during charging and a variable output steam rate during discharging. Demonstrate that the control system can operate successfully during the transients associated with switching from one operating mode to another, and fast start-up or shutdown.

d. Demonstrate that the process equipment designs (heat exchangers, tanks and interconnecting piping) can tolerate anticipated thermal and pressure transients without structural failure.

e. Develop and demonstrate a procedure for initial charging of the Pilot Plant Thermal Storage Subsystem.

2.2 Secondary Objectives - These additional objectives will be met in the course of the test program:

a. Develop control and operating experience with a Thermal Storage Subsystem of the planned design.

b. Experimentally establish system heat losses and their effect on the storage system efficiency.

c. Identify design deficiencies and corrections to be incorporated

3.0 EXPERIMENT DESCRIPTION AND GEORGIA POWER COMPANY INTERFACES - The Thermal Storage Subsystem Research Experiment will be erected at the Georgia Power Company's Plant Yates and the plant will supply superheated steam required to charge the thermal storage system and high pressure feedwater required to discharge the system.

3.1 Test Site Description - The site of the Research Experiment will be a triangular-shaped plot of land approximately one-half acre in area, located immediately northwest of Unit Number 1 at Plant Yates. Drawing A-1759E1, Sheet 1, shows site survey information and the location of major system components. The Research Experiment site is surrounded on two sides by roadways and on one side by a pipe trestle and earth embankment. The Research Experiment will occupy about one-third acre adjacent to the pipe trestle. The site is substantially level and test drillings show that it lies on virgin earth suitable for equipment foundations. A sewer leading to the plant drain system is within the boundaries of the site and the high pressure steam and water lines will be supported on the pipe trestle extending north from Unit Number 1.

3.2 Research Experiment Schematic - The schematic of the Thermal Storage Subsystem Research Experiment is shown on drawing A-1759-R-D-0018-3. During the charging mode of operation, superheated steam is received from the Georgia Power Company, desuperheated in the heat exchanger HE1, condensed in the heat exchanger HE2, subcooled in the heat exchanger HE3, and the subcooled water is discharged to the silencer S1. The energy removed from the steam in HE1 raises the temperature of a molten salt storage medium which is flowing in the circuit from the cooler salt reservoir T2, through HE1, to the hotter salt reservoir T1. The energy removed from the steam in HE2 and HE3 is used to raise the temperature of a hydrocarbon oil storage medium flowing in the circuit from the cooler oil reservoir, T4, through HE3 and HE2, to the hotter oil reservoir T3.

During the discharging mode of operation, the steam flows in the system are reversed and the energy contained in the two storage media is used to convert feedwater into superheated steam. High pressure feedwater that is received from the Georgia Power Company is preheated in HE3, evaporated in HE2, superheated in HE1, and discharged to the silencer.

Water can be injected at the spray desuperheaters DS1 and DS2 to moderate steam temperatures and oil can be bypassed around HE3 to balance heat loads. The control loops are described in Section 5.0 of this test plan.

3.3 Georgia Power Company Interfaces - The Georgia Power Company will supply superheated steam for charging of the Thermal Storage Subsystem Research Experiment and high pressure feedwater for discharging. In addition to feedwater for discharging thermal storage, small quantities of high pressure water will be used during operation in the charging mode for desuperheating steam in order to control temperatures at particular points in the system. The steam and feedwater conditions are given in Table 3.3.1

The Georgia Power Company will also supply electrical power for operation of the Research Experiment (480 volts, 200 amps, 3 phase, to be available on a utility pole at the experiment site), plant service water (unfiltered river water at 65 gal/min), potable water, and a sewer leading to the plant drain system. All used water will be dumped to the drain system rather than returned to the plant water supplies.

The physical interface between the Georgia Power Company and Georgia Tech for the steam and water piping is a point on the pipe trestle just outside the wall of the Unit Number 1 building as shown on drawing A-1759E1, Sheet 2. Georgia Power will make all necessary connections inside the building and pipe the steam and water to the interface point.

The discharge products from the Research Experiment will be steam or hot water which will be piped to a silencer. The silencer consists of a vessel similar in design to an automobile muffler, packed with stainless steel wool. During the charging mode of operation the silencer will discharge both steam and water and during the discharging mode the silencer will discharge steam. The steam will be vented to the atmosphere and water will be placed in a holding tank until its temperature and purity are acceptable for dumping to the plant drain system. In the event that oil or salt are spilled, these will be held at the experiment site until suitable arrangements for disposal are made.

TABLE 3.3.1

CONDITIONS FOR STEAM AND FEEDWATER SUPPLIED BY GEORGIA POWER COMPANY

Stream	Temperature		Pressure		Approximate Flow Rate	
	(K)	(°F)	(kPa)	(psi)	(kg/hr)	(lb/hr)
Charging steam	783	950	8619	1250	3247	7159
Desuperheating water	505	450	9653	1400	205	450
Discharging	505	450	9653	1400	3260	7187

3.4 Operations Control - The operations crew for the Research Experiment consists of four engineers: 1) The Test Conductor, 2) The Console Operator, 3) The Field Operator and 4) The Data Analysis. This staff will be augmented by technicians when the need arises. Operation of the Research Experiment is centered in the control trailer. The trailer layout is illustrated in MMC drawing EPL 6301504, Sheet 3. The trailer contains the control console, the strip chart recorders, work tables, desks, a bookcase and file cabinets. Communication between crew members in the trailer and personnel in the field will be maintained through two-way radios. Standard industrial safety practices will be followed by operations personnel. The crew members will follow the instructions in the Research Experiment detailed procedures when executing the tests outlined in this test plan.

Communications with the supervisory personnel of Plant Yates will be maintained by telephone. The plant supervisor will be notified when steam or feedwater is to be admitted to the Research Experiment. The supervisor will dispatch a member of his staff to open the appropriate valves. The same procedure will be followed when the supply of steam or feedwater is to be shut off, with one exception. In the event of a failure of steam or feedwater piping in the Research Experiment, a member of the Research Experiment crew will immediately be dispatched to close the Georgia Power Company valves. At the same time, the plant supervisor will be notified of the failure by phone.

4.0 INSTRUMENTATION REQUIREMENTS - This section defines the instruments to be used in the Thermal Storage Subsystem Research Experiment. The control loops and logic are described in Section 5.0

4.1 Instrumentation List - The sensors are listed by type, temperature sensor, flow rate sensors, ect., in Table 4.1.1. The outputs from every sensor will be recorded in order to document the experimental runs; certain sensors also have a control function as described in Section 5.0. The position

TABLE 4.1.1

INSTRUMENTATION LIST

No.	Transducer	Control Circuit	Purpose
1	CTS1 (Charing Temp Sensor # 1)	Charging Control Circuit # 2	Senses temp of superheated steam leaving HE1
2	DSTS (Desuperheater Temp Sensor)	Charging Control Circuit # 3	Senses temp of superheated steam leaving DS2
3	DTS1 (Discharging Temp Sensor # 1)	Charging Control Circuit # 6	Senses temp of superheated steam leaving DS1
4	DTS2 (Discharging Temp Sensor # 2)	Property Recording Circuit # 2	Senses temp of feedwater leaving Research Experiment
5	DTS3 (Discharging Temp Sensor # 3)	Discharging Control Circuit # 1	Senses temp of feedwater exiting HE3
6	DTS1 (Discharging Temp Sensor # 1)	Discharging Control Circuit # 4	Senses temp of superheated steam exiting Research Experiment during discharge
7	TS1 (Temp Sensor # 1)	Property Recording Circuit # 2	Senses temp of heat transfer salt line between T1 and HE1
8	TS2 (Temp Sensor # 2)	Property Recording Circuit # 2	Senses temp of heat transfer salt line between T2 and HE1
9	TS3 (Temp Sensor # 3)	Property Recording Circuit # 6	Senses temp of salt tank # 1
10	TS4 (Temp Sensor # 4)	Property Recording Circuit # 6	Senses temp of salt tank # 1

(Continued)

TABLE 4.1.1 (Continued)

INSTRUMENTATION LIST

No.	Transducer	Control Circuit	Purpose
11	TS5 (Temp Sensor # 5)	Property Recording Circuit # 6	Senses temp of salt tank # 1
12	TS6 (Temp Sensor # 6)	Property Recording Circuit # 8	Senses temp of salt tank # 2
13	TS7 (Temp Sensor # 7)	Property Recording Circuit # 8	Senses temp of salt tank # 2
14	TS17 (Temp Sensor # 17)	Property Recording Circuit # 4	Senses temp of oil line between T4 and HE3
15	TS20 (Temp Sensor # 20)	Property Recording Circuit # 4	Senses temp of oil line between HE3 and HE2
16	TS18 (Temp Sensor # 18)	Property Recording Circuit # 4	Senses temp of oil line between HE2 and T3
17	TS8 (Temp Sensor # 8)	Property Recording Circuit # 10	Senses temp of oil tank T3
18	TS9 (Temp Sensor # 9)	Property Recording Circuit # 10	Senses temp of oil tank T3
19	TS10 (Temp Sensor # 10)	Property Recording Circuit # 10	Senses temp of oil tank T3
20	TS11 (Temp Sensor # 11)	Property Recording Circuit # 12	Senses temp of oil tank T4
21	TS12 (Temp Sensor # 12)	Property Recording Circuit # 12	Senses temp of oil tank T4
22	TS14 (Temp Sensor # 14)	None (Override Control)	Senses temp of steam exiting into safety receiver

(Continued)

TABLE 4.1.1 (Continued)

INSTRUMENTATION LIST

No.	Transducer	Control Circuit	Purpose
23	TS21 (Temp Sensor # 21)	None (Override Control)	Senses temp of steam exiting into safety receiver
24	TS15 (Temp Sensor # 15)	None (Override Control)	Senses temp of stean exiting into safety receiver
25	TS16 (Temp Sensor # 16)	None (Override Control)	Senses temp of steam exiting into safety receiver
26	SCTC1 (Surface Temp Sensor # 1)	None (Readout Meter)	Senses steam temp at FRS1
27	SCTC2 (Surface Temp Sensor # 2)	None (Readout Meter)	Senses feedwater temp at FRS2
28	SCTC3 (Surface Temp Sensor # 3)	None (Readout Meter)	Senses oil temp out of HE5
29	SCTC4 (Surface Temp Sensor # 4)	None (Readout Meter)	Senses oil temp into HE5
30	SCTC5 (Surface Temp Sensor # 5)	None (Readout Meter)	Senses feedwater temp at FRS5
31	SCTC6 (Surface Temp Sensor # 6)	None (Readout Meter)	Senses feedwater temp at FRS6
32	SCTC7 (Surface Temp Sensor # 7)	None (Readout Meter)	Senses oil temp out of HE3
33	SCTC8 (Surface Temp Sensor # 8)	None (Readout Meter)	Senses steam temp at FRS8
34	SCTC9 (Surface Temp Sensor # 9)	None (Readout Meter)	Senses water temp at FRS9

(Continued

TABLE 4.1.1 (Continued)

INSTRUMENTATION LIST

No.	Transducer	Control Circuit	Purpose
35	SCTC10 (Surface Temp Sensor # 10)	None (Readout Meter)	Senses salt temp between HE1 units
36	SCTC11 (Surface Temp Sensor # 11)	None (Readout Meter)	Senses temp of water in HE2 recirculation line
37	SCTC12 (Surface Temp Sensor # 12)	None (Readout Meter)	Senses temp of head of HE1
38	SCTC13 (Surface Temp Sensor # 13)	None (Readout Meter)	Senses temp of head of HE1
39	SCTC14 (Surface Temp Sensor # 14)	None (Readout Meter)	Senses temp of head of HE1
40	SCTC15 (Surface Temp Sensor # 15)	None (Readout Meter)	Senses temp of head of HE1
41	SCTC16 (Surface Temp Sensor # 16)	None (Readout Meter)	Senses temp of top head of HE2
42	SCTC17 (Surface Temp Sensor # 17)	None (Readout Meter)	Senses temp of bottom head of HE2
43	SCTC18 (Surface Temp Sensor # 18)	None (Readout Meter)	Senses temp of head of HE3
44	SCTC19 (Surface Temp Sensor # 19)	None (Readout Meter)	Senses temp of head of HE3
45	SCTC20 (Surface Temp Sensor # 20)	None (Readout Meter)	Senses temp of condensate at DV1
46	SCTC21 (Surface Temp Sensor # 21)	None (Readout Meter)	Senses temp of condensate at DV4

(Continued)

TABLE 4.1.1 (Continued)

INSTRUMENTATION LIST

No.	Transducer	Control Circuit	Purpose
1	FRS1 (Flow Rate Sensor # 1)	Charging Control Circuit # 1	Senses flow rate of superheated steam into Research Experiment
2	FRS8 (Flow Rate Sensor # 8)	Discharging Control Circuits # 2 & # 5	Senses flow rate of superheated steam exiting Research Experiment during discharge
3	FRS2 (Flow Rate Sensor # 2)	Discharging Control Circuit # 2	Senses flow rate of feedwater into Research Experiment
4	FRS3 (Flow Rate Sensor # 3)	Property Recording Circuit # 1	Senses flow rate of salt line between T1 and FCV1 during discharging
5	FRS7 (Flow Rate Sensor # 7)	Property Recording Circuit # 1	Senses flow rate of salt line between T1 and FCV1 during charging
6	FRS4 (Flow Rate Sensor # 4)	Property Recording Circuit # 3	Senses flow rate of oil in pump to HE2 line during charging
7	FRS10 (Flow Rate Sensor # 10)	Property Recording Circuit # 3	Senses flow rate of oil in pump to HE3 line during discharging
8	FRS5 (Flow Rate Sensor # 5)	Property Recording Circuit # 13	Senses flow rate of feedwater line to DS1
9	FRS6 (Flow Rate Sensor # 6)	Property Recording Circuit # 14	Senses flow rate of feedwater line to DS2

(Continued)

TABLE 4.1.1 (Concluded)

INSTRUMENTATION LIST

No.	Transducer	Control Circuit	Purpose
10	FRS9 (Flow Rate Sensor # 9)	Property Recording Circuit # 15	Senses flow rate of discharge condensate line to silencer
11	FRS11 (Flow Rate Sensor # 11)	Property Recording Circuit # 15	Senses flow rate of water in HE2 recirculation line
1	LLS4 (Liquid Level Sensor # 4)	Charging Control Circuit # 4	Senses condensate level in HE2 during charging
2	LLS1 (Liquid Level Sensor # 1)	Discharging Control Circuit # 2	Senses liquid level in seperator of HE2 during discharge
3	LLS2 (Liquid Level Sensor # 2)	Property Recording Circuit # 5	Senses level of salt tank # 2 (T1)
4	LLS5 (Liquid Level Sensor # 5)	Property Recording Circuit # 9	Senses level of oil tank # 1 (T3)
1	CPS1 (Charging Press Sensor # 1)	Charging Control Circuit # 5	Senses condensing press in HE2 during charging
2	DPS1 (Discharging Press Sensor # 1)	Discharging Control Circuit # 3	Senses press of superheated steam exiting Research Experiment

of each sensor on the schematic may be identified by referring to drawing A-1759-R-D-0018-3.

4.2 Data Recording and Reduction - Hard copy records (strip chart recordings) of each sensor output will be made in order to preserve permanent records of raw performance data. All control functions will be accomplished by Electronic Control Systems, Inc., Model 6812 controllers incorporated into the Research Experiment. Data may be read and reduced by manual techniques and automatic data processing techniques.

4.3 Thermocouple Junction Box - Forty surface contact thermocouples are available to monitor temperatures that are considered necessary for safe operation of the system or for system performance analysis. This number does not include the thermocouples that are used for system control. The locations of 21 of the surface contract thermocouples has been determined. These 21 locations are shown on the Research Experiment Schematic as SCTC's and their function is listed in Table 4.1.1. Nineteen thermocouples are held in reserve so that they can be used when operational experience indicates the need for additional temperature information. All of the surface contact thermocouples will run to a reference junction box which is located at the base of salt tank number one. In the junction box, which maintains a constant internal temperature of 339 K (150°F), the thermocouple wires will be joined to copper leads that will extend to the instrumentation inside the control trailer.

5.0 PROCESS CONTROL IN THE RESEARCH EXPERIMENT - The Thermal Storage Subsystem Research Experiment will employ state-of-the-art control devices operating with control logic identical to that anticipated in the Pilot Plant. The control loops are listed in Table 5.0.1 and illustrated on the schematic, drawing A-1759-R-D-0018-3.

During the charging mode of operation, the input steam flow rate must simulate the variable flow rate characteristic anticipated in a Solar Thermal Pilot Plant. This will be accomplished by manual adjustment of the set point on a controller. All other controls will be automatic as shown in Table 5.0.1.

During the discharging mode of operation, the output steam flow rate must follow the variable characteristic anticipated for a turbine in the load following mode. This will also be accomplished by manual adjustment of the set point on a controller. All other controls will be automatic.

Three overall control modes are anticipated: CHARGE, STANDBY, and DISCHARGE. In each of these modes, the appropriate control configurations will be established automatically; for example, certain control loops will be placed in operation and others will be disconnected. All control loops will have a manual override capability to permit an operator to perform special operations, such as bleeding pressure from the system. During system operation, the pressure is normally controlled by the oil flow rate in heat exchanger HE2.

The control console for the Research Experiment is illustrated on MMC drawing EPL 6301501, Sheet 2. The console is layed out

TABLE 5.0.1

PROCESS CONTROLS IN THE RESEARCH EXPERIMENT

Circuit Name	Major Components	Function
Charging Control Circuit # 1	Flowrate Sensor # 1, Controller and Set Point, Strip Chart Recorder, Totalizer, Flow Control Valve # 5	Controls flow of steam into Research Experiment and simulates output of solar power boiler
Charging Control Circuit # 2	Charging Temperature Sensor # 1, Controller and Set Point, Strip Chart Recorder, Flow Control Valve # 1	Controls heat transfer salt flow through HE1 to maintain steam exit temperature from HE1
Charging Control Circuit # 3	Desuperheater Temperature Sensor, Controller and Set Point, Strip Chart Recorder, Flow Control Valve # 4	Controls feedwater flow into DS2 through FCV4 to maintain fixed steam temperature into HE2
Charging Control Circuit # 4	Liquid Level Sensor # 4, Controller and Set Point, Strip Chart Recorder, Flow Control Valve # 8	Maintains liquid level in HE2 during charging by controlling condensate exiting system through FCV8
Charging Control Circuit # 5	Charging Pressure Sensor # 1, Controller Set Point, Strip Chart Recorder, Flow Control Valve # 2	Controls oil flow rate into HE3 through FCV2 in order to maintain constant condensing pressure in HE2

(Continued)

TABLE 5.0.1 (Continued)

PROCESS CONTROLS IN THE RESEARCH EXPERIMENT

Circuit Name	Major Components	Function
Charging Control Circuit # 6	Discharging Temperature Sensor #1, Controller and Set Point, Strip Chart Recorder, Flow Control Valve # 7	Controls flowrate of feedwater into DS1 through FCV7 to maintain constant steam temperature into HE1
Discharging Control Circuit #1	Discharge Temperature Sensor # 3, Controller and Set Point, Strip Chart Recorder, Flow Control Valve # 11	Controls amount of oil into HE3 through FCV11 in order to maintain constant feedwater temperature into HE2
Discharging Control Circuit #2	Flowrate Sensor # 8, Flowrate Sensor # 2, Liquid Level Sensor # 1, Controller and Set Point, Strip Chart Recorder, Flow Control Valve # 9	Three element feedwater controller that controls the feedwater flow rate through FCV9 into the Research Experiment
Discharging Control Circuit #3	Discharge Pressure Sensor # 1, Controller and Set Point, Strip Chart Recorder, Flow Control Valve # 2	Controls oil flow rate into HE2 through FCV2 in order to maintain a constant output pressure during discharge

(Continued)

TABLE 5.0.1 (Concluded)

PROCESS CONTROLS IN THE RESEARCH EXPERIMENT

Circuit Name	Major Components	Function
Discharging Control Circiut # 4	Discharge Temperature Sensor # 1, Controller and Set Point, Strip Chart Recorder, Flow Control Valve # 1	Controls flow of HTS into HE1 through FCV1 to maintain constant superheated steam temperature during discharge
Discharging Control Circuit # 5	Flowrate Sensor # 8, Controller and Set Point, Strip Chart Recorder, Flow Control Valve # 6	Controls flow of steam exiting Research Experiment and simulates demand from electric power generating turbine.

to resemble the operational schematic as much as possible. The major components are in the same relative locations and the steam and feedwater circulation lines have the same orientation. The output from all of the flow rate sensors, liquid level sensors and most of the temperature sensors can be read from meters located in the panel in their proper schematic locations.

Operation of the Research Experiment requires nine electronic controllers. The controllers, which will be Electronic Control Systems, Inc., Model 6812 units, are located in a row across the center portion of the control panel. The nominal valve of the process variable to be controlled is manually set on a digital dial on the face of the controller. Controller output and deviation from set point meters are located on the face of the controller. Two of the controllers are dual function controllers in the sense that these units control one process variable during charging and a different variable during discharging. The input to the FCV1 controller will come from DTS1 during discharging and from CTS1 charging. The input for the FCV2 controller will come from DPS1 during discharging and from CPS1 during charging. When the Research Experiment is turned around from the charging mode to the discharging mode of operation, the set points of these controllers will have to be changed. The control action of both controllers must be reversed by a switch located on the side of each unit. The rest of the controllers on the panel are single function units and they will not have to be adjusted during a mode reversal of the Research Experiment.

The mode selection switches for charge, discharge and standby are located on the panel between the two salt tank lines. The standby override switch for each controller is positioned directly below its respective unit. This switch removes the ground from the controller output and allows actuation of the flow control valves in the standby mode. Manual switches are located next to each flow reversing valve on the control console. These switches open the corresponding valves in the standby mode.

6.0 PRELIMINARY SYSTEM TESTS - A series of preliminary system tests will be conducted for the purpose of system checkout and trouble-shooting; these tests precede the performance test sequence. The contractors who install the equipment will perform hydro-static testing for detecting leaks, and correct any leaks found, before Georgia Tech assumes control of the Research Experiment hardware. The preliminary tests performed by Georgia Tech will consist of:

a. Cleaning,

b. Checkout of individual control circuits, and

c. Initial system start-up and checkout of the control system.

6.1 The Research Experiment will be cleaned after assembly and before operation. Only the steam and feedwater lines and the tube side of the heat exchangers will be cleaned. A combination of superheated steam and feedwater will be flushed through the system to accomplish the cleaning.

6.2 Checkout of Individual Control Circuits - The control circuit checkout tests will consist of applying a simulated sensor input and verifying the circuit response, typically the actuation of a valve. The controls which operate the molten salt transfer loop, the oil transfer loop, the oil bypass loop, the two spray desuperheaters and the condenser-evaporator liquid levels will be checked in this manner. Operation will be checked to verify that the controls respond in the proper direction and that actuation occurs at the desired set points.

6.3 Initial System Startup and Control System Checkout - The oil stage will be initially charged and operated without the salt stage. The run sequence will include:

a. Preheating of the steam circuit, including piping and heat exchangers. This procedure will verify operation of:

(1) Steam admission valve and controller,

(2) The two spray desuperheaters and their controllers,

(3) The feedwater exit valve to the silencer and its controller.

b. Initial charging of the oil system, including raising of the oil temperature to design operating level. The oil will be heated to its operating temperature of 500°F by passing it through the oil heat exchangers three times. Each pass, the oil temperature will be raised approximately 200°F. The steam will be spray desuperheated down to a temperature that is appropriate for each of the heating passes. These runs will verify the operation of:

(1) Oil flow throttling valve and controller in the charging mode,

(2) Oil flow reversing valves,

(3) The functioning of HE2 as a condenser,

(4) The functioning of HE3 as a subcooler, and

(5) The operation of the liquid level control system LLS4 on HE2.

c. Initial discharging of oil system, at approximately 50 percent of the maximum design rate. This test will verify the operation of:

(1) The feedwater admission valve and controller,

(2) The steam exit valve to the silencer and its controller,

(3) The oil flow throttling valve and controller in the discharging mode,

(4) The oil bypass system around HE3 and its controller,

(5) The operation of HE2 as an evaporator,

(6) The operation of HE3 as a preheater, and

(7) The operation of the three-element feedwater controller.

d. Initial charging of the molten salt stage, including raising of the salt temperature to design operating level. The heat transfer salt will already have been loaded into the two salt storage tanks and melted by the steam coils in these tanks. The oil stage will be operated during the salt charging process in order to condense the steam discharged from the salt stage. This test will verify the operation of the molten salt flow control valve and its controller in the charging mode.

e. Initial discharging of the Research Experiment. The entire system will be operated in the discharging mode at approximately 1,588 kg/hr (3,500 lb/hr), 50 percent of the maximum discharging rate. This test will verify the operation of the molten salt flow control valve and its controller in the discharging mode.

7.0 PERFORMANCE TEST SEQUENCE - This sequence represents the tests which are intended to demonstrate the technical feasibility and to establish the performance capabilities of the thermal storage system concept. The performance test sequence will be divided into two categories of progressively more complex operations. This pattern permits the learning value of less complex runs, such as those with steady flow rates, to be applied to more complex runs, such as those with transient flow rates. The categories of performance tests will be:

a. Constant rate charging and discharging operations which must be completed in order to achieve the objectives given in paragraphs 2.1a and 2.1b, and

b. Transient charging and discharging operations which must be completed in order to achieve the objectives given in paragraphs 2.1c and 2.1d.

The objective listed in paragraph 2.1e will be met during the preliminary testing and those listed in paragraph 2.2 will be attained throughout the course of the test program.

7.1 Constant rate charging and discharging tests - These performance tests will be conducted in the following order:

a. The charging steam flowrate will be slowly brought from zero to 50% of full flow on a linear ramp. The system will be allowed to charge at this rate for a length of time such that after the flowrate has been reduced from 50% of full charging flow to 0 flow on a slow linear ramp, the system will be fully charged.

b. The discharge steam flowrate will be increased from 0 to 50% of full discharge flowrate on a slow linear ramp. The system will be allowed to discharge at this rate for a length of time such that after the flowrate has been reduced from 50% of full discharging flow to 0 flow on a slow linear ramp the system will be fully discharged.

c. The charging steam flowrate will be brought from zero to full flow on a linear ramp that is typical of normal pilot plant operation. The system will be allowed to charge at full rate for a length of time such that after the flowrate has been reduced from full flowrate to 0 flowrate on a linear ramp that is typical for normal pilot plant operation the system will be fully charged.

d. The discharge steam flowrate will be increased from 0 to full flowrate on a linear ramp, this ramp rate will be consistent with normal pilot plant ramp rates. The system will be allowed to discharge at this rate for a length of time such that after the flowrate has been reduced from full discharging flowrate to zero flow on a linear ramp (the ramp consistent with normal pilot plant rates) the system will be fully discharged.

e. The charging steam flowrate will be brought from zero to 20% full flow on a linear ramp that has a ramp rate that represents the maximum ramp rate expected under normal pilot plant operation. The system will be allowed to charge at this rate for a length of time such that after the flowrate has been reduced from full flowrate to zero flowrate on a linear ramp (maximum normal operation ramp) the system will be fully charged.

f. The discharge steam flowrate will be increased from 0 to 20% of full flowrate on a linear ramp that has a ramp rate that represents the maximum ramp rate expected under normal pilot plant operation. The system will be allowed to discharge at this rate for a length of time such that after the flowrate

d. Immediately following the charging shutdown under c, the sequence for fast turn-around from charge to discharge will be demonstrated. The discharge flowrate will come up following a typical turbine startup flowrate. The discharge flowrate shutdown will follow a typical turbine shutdown from storage.

e. Immediately following the discharge shutdown under d, the sequence for fast turn-around from discharge to charge will be demonstrated. The charge flowrate will be taken to full flow then reduced to zero without fully charging the storage system.

f. The tests under c, d and e will be repeated (this test will demonstrate the repeatability of the system).

g. The system will be put into a charging mode at 100% of design flow. The flow will come up on maximum expected pilot plant ramp rate. The flow will ramp down in a manner simulating the flowrate decay caused by a cloud covering the heliostat field.

h. Immediately following the charging shutdown under g, a fast charging to discharging turn-around will be demonstrated. The system will be ramped up to maximum discharging flowrate on a ramp that represents maximum expected pilot plant ramps. Then the discharging flow will be terminated simulating a turbine trip.

has been reduced from full discharging flowrate to zero flowrate on a linear ramp (maximum normal operation ramp) the system will be fully discharged.

7.2 Transient Charging and Discharging Test - These tests will be conducted in the following order:

a. Charge steam flowrate will be ramped up on a linear rate to 100% of full flow. The system will then be allowed to come to steady state temperatures and pressures. After steady state has been achieved then the steam flow rate will be ramped down to 50% of full flow. The ramp down flow rate will be at the maximum expected for the pilot plant. The system will be maintained at 50% of maximum charging rate until the charge is complete.

b. Discharge steam flowrate will be ramped up on a linear rate to 100% of full flow. The system will then be allowed to come to steady temperatures and pressures. After steady state has been achieved then the steam flow rate will be ramped down to 50% of full flow. The ramp down flowrate will be at the maximum expected for the pilot plant. The system will be maintained at 50% of maximum discharging rate until the discharge is complete.

c. Charge following a typical sun-up receiver steam generation flow rate up to full flow, terminate the charge with a typical receiver evening shutdown.

Successful completion of thest tests will accomplish all of the objectives of the Research Experiment Test Program.

APPENDIX A

REFERENCED DOCUMENTS

The following documents are referenced in the Test Plan:

1) Thermal Storage System Research Experiment Procedures

2) GIT Drawing A1759E1, Sheets 1 and 2, Mechanical Installation

3) GIT Drawing A1759-R-D-0018-3, Research Experiment Schematic

4) MMC Drawing EPL 6301501, Sheet 2, Control Console

5) MMC Drawing EPL 6301504, Sheet 4, Viking Trailer Concept

APPENDIX B

SUPPORTING DOCUMENTS

The following drawings are supporting document to the Test Plan:

1) A1759E1 Mechanical Installation
2) A1759E2 Structural Details
3) A1759E3 Instrumentation and Controls Installation
4) A1759E4 Desuperheater Assembly
5) A1759E5 Valve Air Supply Schematic
6) A1759-R-D-1002-4 Electrical Installation
7) A1759-R-D-0018-3 Research Experiment Schematic
8) EPL 6301501 Control Console
9) EPL 6301399 Control & Monitor Diagram
10) EPL 6301504 Junction Box Field Interface